Copy #12

OPERATING INSTRUCTIONS

ALLIS-CHALMERS FUEL CELL POWER SYSTEM

(SYSTEM NUMBER 5R)

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MARSHALL SPACE FLIGHT CENTER

Huntsville, Alabama

ALLIS-CHALMERS
RESEARCH DIVISION

NASA Fuel Cell Systems Program
Milwaukee, Wisconsin

June 6, 1966

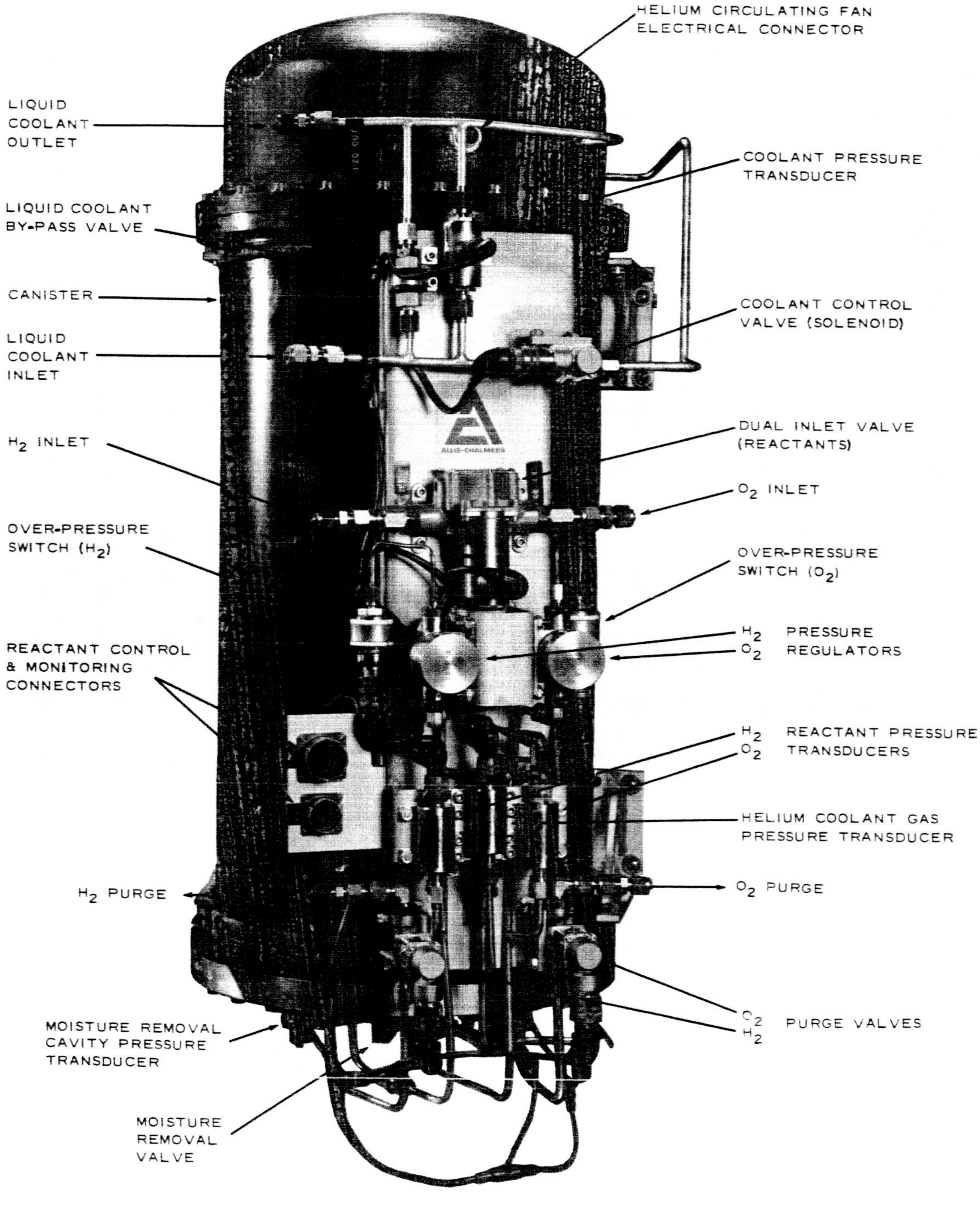

HELIUM CIRCULATING FAN ELECTRICAL CONNECTOR
LIQUID COOLANT OUTLET
COOLANT PRESSURE TRANSDUCER
LIQUID COOLANT BY-PASS VALVE
CANISTER
COOLANT CONTROL VALVE (SOLENOID)
LIQUID COOLANT INLET
DUAL INLET VALVE (REACTANTS)
H_2 INLET
O_2 INLET
OVER-PRESSURE SWITCH (H_2)
OVER-PRESSURE SWITCH (O_2)
H_2 O_2 PRESSURE REGULATORS
REACTANT CONTROL & MONITORING CONNECTORS
H_2 O_2 REACTANT PRESSURE TRANSDUCERS
HELIUM COOLANT GAS PRESSURE TRANSDUCER
H_2 PURGE
O_2 PURGE
O_2 H_2 PURGE VALVES
MOISTURE REMOVAL CAVITY PRESSURE TRANSDUCER
MOISTURE REMOVAL VALVE

TABLE OF CONTENTS

SECTION I - SYSTEM DESCRIPTION

SECTION II - INSTALLATION INSTRUCTIONS

SECTION III - INTEGRATED SYSTEM OPERATION

SECTION IV - SUBSYSTEM DESCRIPTION

SECTION I

SYSTEM DESCRIPTION

1.1 GENERAL DESCRIPTION OF OPEN LOOP FUEL CELL SYSTEM

The fuel cell system is an electro-chemical device in which the controlled temperature reaction of two input gases, hydrogen and oxygen, in the presence of a suitable electrolyte and electrodes, produces a direct current electrical output. The by-products of the reaction are heat and water which must be removed from the fuel cell. As the gases are consumed in the reaction, minute amounts of gas impurities (inerts) present in the reactant gases accumulate in the cell cavities. To maintain proper system performance, it is necessary to remove these impurities by periodically purging the cell cavities.

The basic operating voltage of the system is fixed by the number of cells, and the combination of electrical connections between the cells. Within the design limits, the load current will follow the demand, provided adequate amounts of reactant gases are supplied to the fuel cell.

This fuel cell is designated as an "asbestos capillary matrix" type in which the potassium hydroxide (KOH) electrolyte is held in a porous asbestos matrix without any circulation.

The by-product water is withdrawn from the fuel cell as vapor. It is produced at the hydrogen electrode, and diffuses into the moisture removal cavity through a KOH impregnated asbestos capillary matrix. The rate of water removal is controlled by maintaining the moisture removal cavity at a pressure equivalent to a predetermined electrolyte concentration. The quantity of water produced is proportional to the current produced by the fuel cell.

In the open loop system the moisture vapor, controlled by the moisture removal valve, is vented to a vacuum source.

Approximately one-third of the by-product heat is removed from the stack by evaporation of the product water. This helps promote good cell and stack temperature control. The majority of the by-product heat is removed from the fuel cell stack by recirculating helium gas over the finned edges of the cell plates. The heated helium gas then passes through a gas-to-liquid heat exchanger where the excess heat is rejected to the liquid coolant after which it is recirculated. The liquid coolant is cooled externally of the fuel cell system. The helium gas is recirculated constantly at a fixed rate by fans and the amount of heat removed from the fuel cell is controlled by controlling the flow of the liquid coolant through the heat exchanger.

1.2 PERFORMANCE CAPABILITY GOALS

The performance capability goals of this fuel cell system are tabulated below:

Nominal Power Rating	2000 watts
Overload	2700 watts (load profile)
Voltage Regulation	27 to 32.5 volts (22 volts min.)
Minimum Voltage (overload)	22 volts
Cell Operating Temperature	195 $\pm$ 5°F
Maximum Reactant Consumption at 2000 watt load	Hydrogen - 0.22 pounds per hour Oxygen - 1.75 pounds per hour
Reactant Inlet Pressure	175-400 psia
Reactant Inlet Temperature	0 to 150°F
Reactant Purity	0.999 min. 0.99998 hydrogen / 0.99995 oxygen Desired
Thermal efficiency (min).	55%
Endurance	1250 Qualification

Liquid Coolant	60% methyl alcohol, 40% water by weight, plus corrosion inhibitors
Liquid Coolant Supply	120 pounds per hour at 60°F
Liquid Coolant Pressure Drop (max.)	15.0 psid

1.3 SYSTEM DIAGRAMS

1.3.1 Figure 1-1 illustrates schematically the complete functional fuel cell open-loop system. The basic input requirements to the open-loop cell assembly are:

Hydrogen Gas

Oxygen Gas

Auxiliary Power Supply for Start-up

Liquid Coolant

Vacuum

Helium Gas

The products removed from the fuel cell assembly are:

Direct Current Electricity

Water

Heat

The specifications for each of the input and output items are detailed in Section 2.1 Fuel Cell Assembly and Section III - INTEGRATED SYSTEM OPERATIONS.

1.3.2 Figure 1-2A, 1-2B and 1-2C (Drawing No. 49-500-125-404) is the Fuel Cell System Schematic illustrating SYSTEM OPERATIONS. A description of the subsystems if found in Section 4.

SCHEMATIC - FUEL CELL POWER SYSTEM

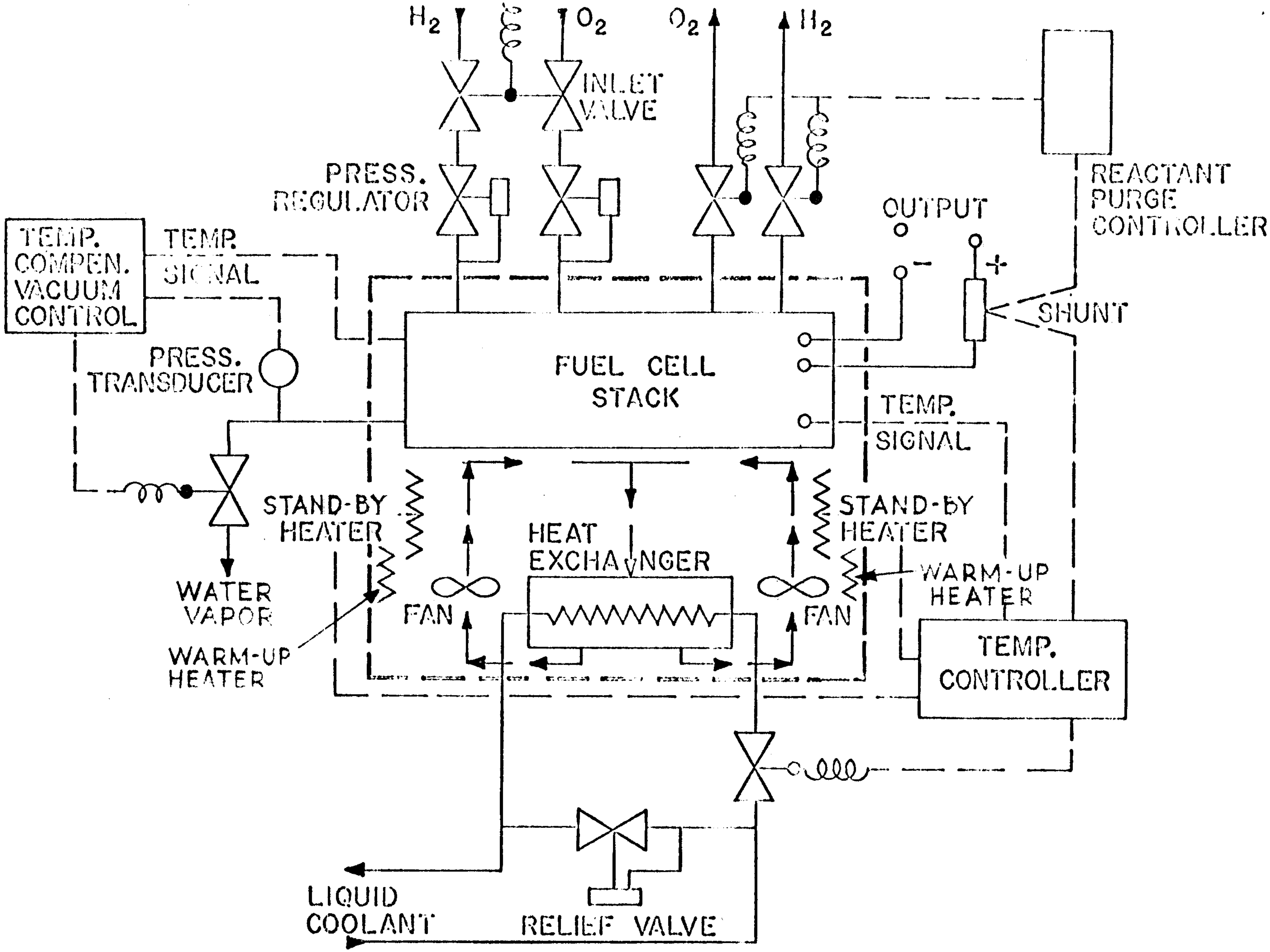
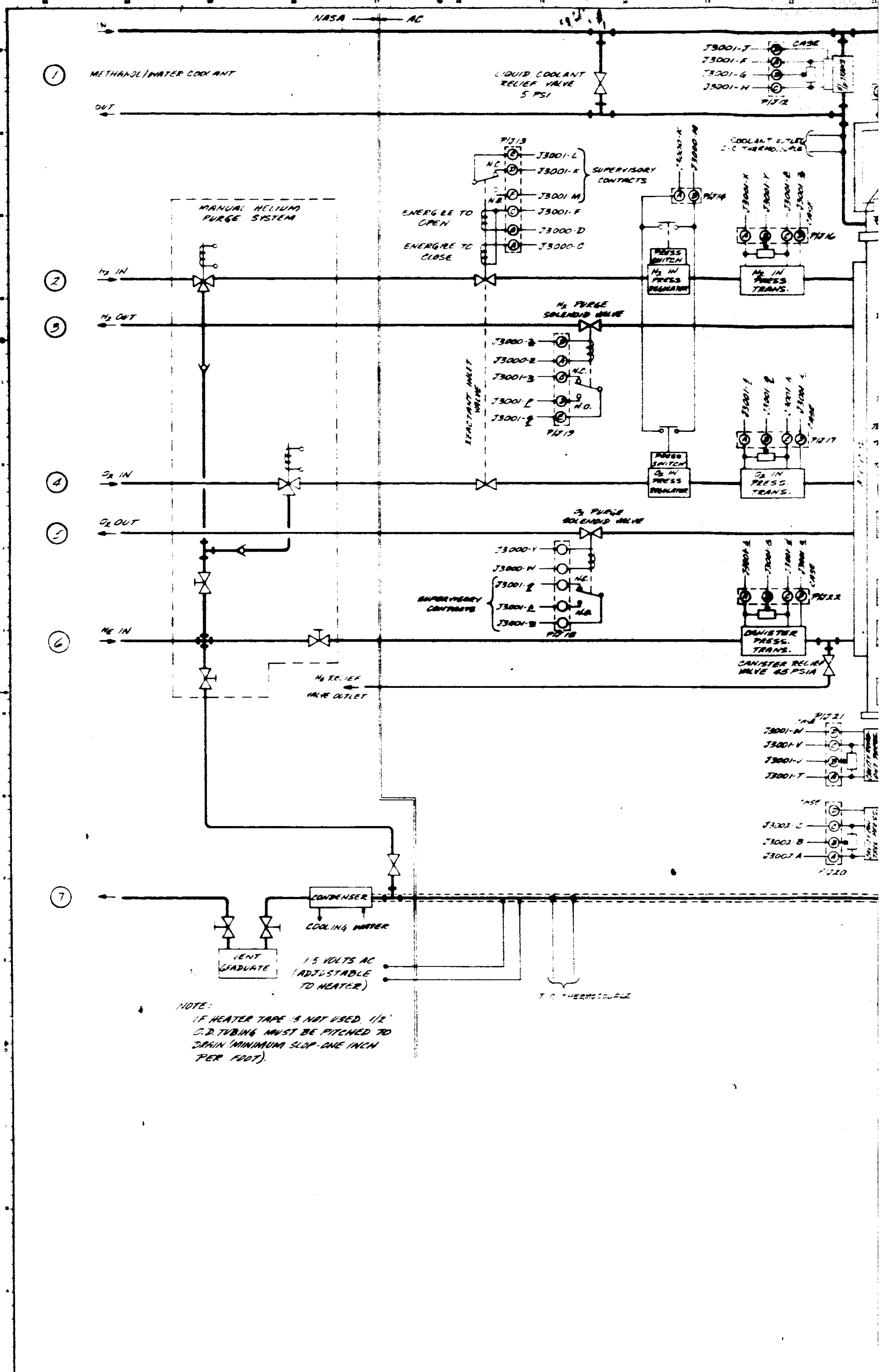
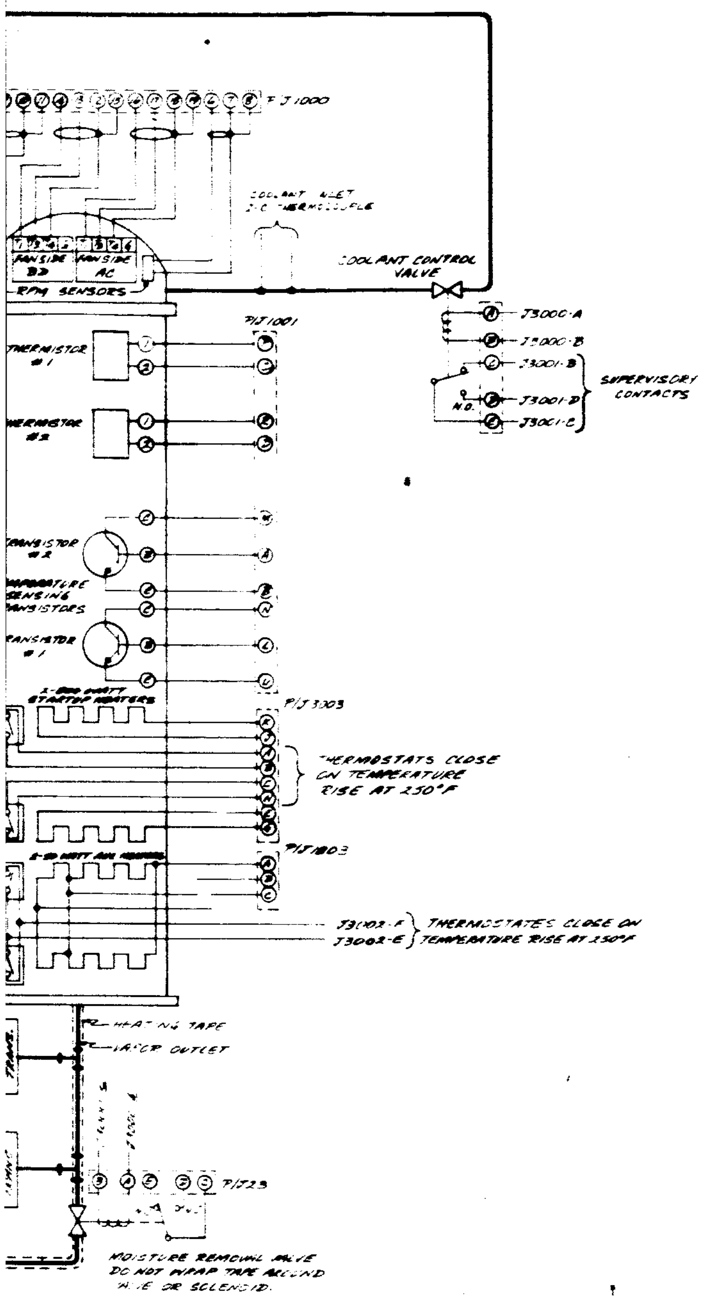


FIG. 1-1


NASA
AC
METHANOL/WATER COOLANT
IN
OUT
LIQUID COOLANT RELIEF VALVE 5 PSI
CASE
COOLANT OUTLET T.C THERMOCOUPLE
SUPERVISORY CONTACTS
MANUAL HELIUM PURGE SYSTEM
ENERGIZE TO OPEN
ENERGIZE TO CLOSE
PRESS SWITCH
H2 IN PRESS REGULATOR
H2 IN PRESS. TRANS.
H2 PURGE SOLENOID VALVE
REACTANT INLET VALVE
N.C.
N.O.
O2 IN PRESS REGULATOR
O2 IN PRESS. TRANS.
O2 PURGE SOLENOID VALVE
SUPERVISORY CONTACTS
CANISTER PRESS. TRANS.
CANISTER RELIEF VALVE 65 PSIA
He RELIEF VALVE OUTLET
CONDENSER
COOLING WATER
VENT GRADUATE
115 VOLTS AC (ADJUSTABLE TO HEATER)
T.C. THERMOCOUPLE
NOTE:
IF HEATER TAPE IS NOT USED, 1/2" O.D. TUBING MUST BE PITCHED TO DRAIN (MINIMUM SLOP-ONE INCH PER FOOT).

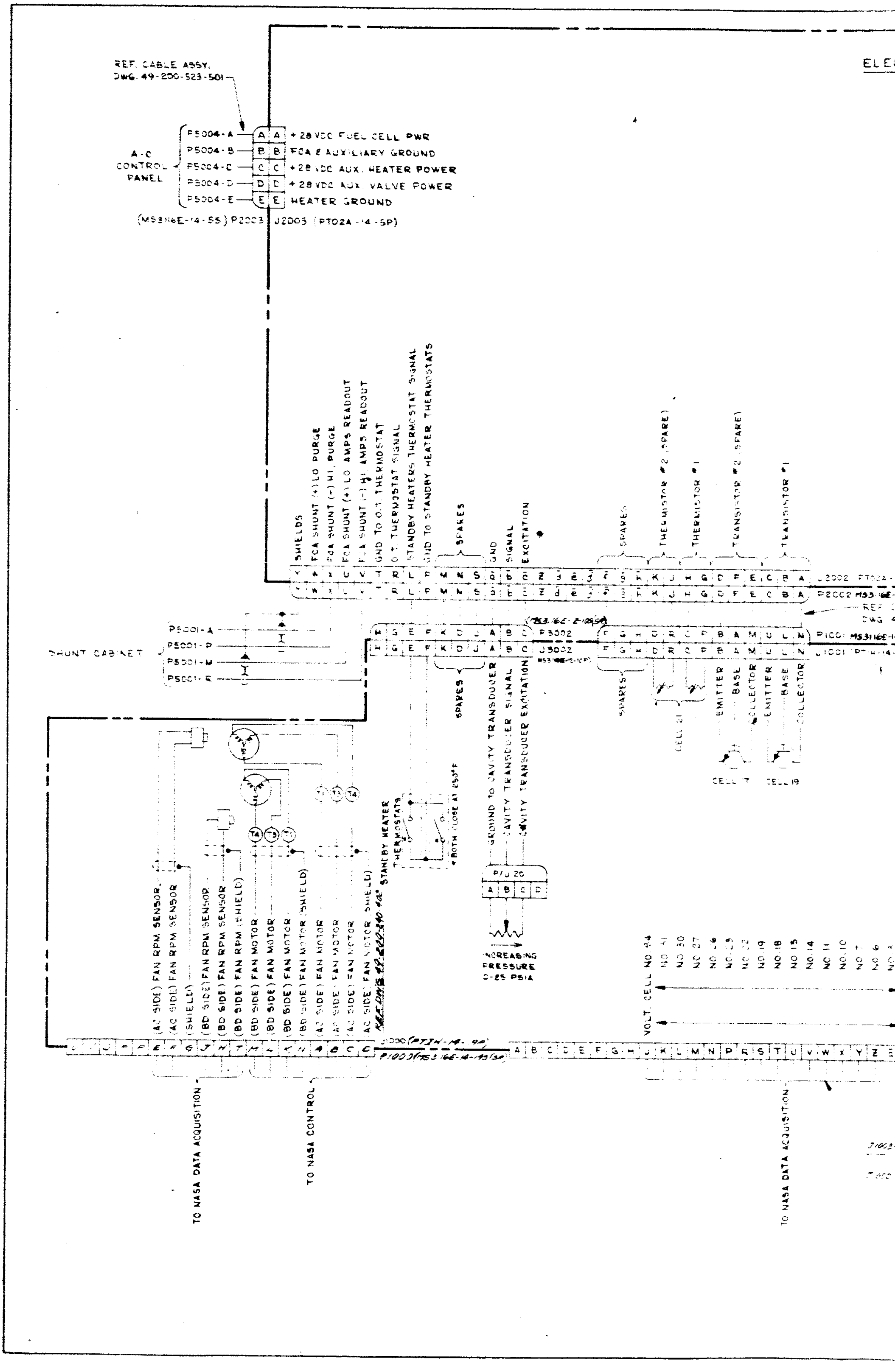


NOTES:

1. LIQUID COOLANT - 60% MENTHYL ALCOHOL (BY WEIGHT) 40% WATER. FLOW RATE: 50 LBS/HR, MAX. INLET TEMP. 60°F MAX. OUTLET TEMP: 100°F. ΔP: 5 PSI.
2. HYDROGEN IN - 99.98% PURITY, MAXIMUM FLOW RATE SHALL BE 0.22 LBS/HR AT A FUEL CELL LOAD OF 80 AMPERES AND AN ADDITIONAL 0.[illegible] LBS/HR (0.[illegible] LBS/HR TOTAL) DURING PURGING. INLET CONDITIONS: TEMPERATURE - 0°F TO 50°F; PRESSURE - 175 PSIA TO 400 PSIA.
3. HYDROGEN PURGE OUTLET - OCCURS EVERY 20 AMP-HOURS. DURATION OF INITIAL PURGE AND AUTOMATIC SCHEDULED PURGE IS 60 SECONDS AT A RATE OF 0.39 LBS/HOUR.
4. OXYGEN IN - 99.996% PURITY. MAXIMUM FLOW RATE SHALL BE 1.75 LBS/HR AT A FUEL CELL LOAD OF 80 AMPERES AND AN ADDITIONAL 5.5 LBS/HR (7.25 LBS/HR TOTAL) DURING PURGING. INLET CONDITIONS: TEMPERATURE - 0°F TO 50°F; PRESSURE - 75 PSIA TO 400 PSIA.
5. OXYGEN PURGE OUTLET - OCCURS EVERY 80 AMP-HOURS. DURATION OF INITIAL PURGE AND AUTOMATIC SCHEDULED PURGE IS 60 SECONDS AT A RATE OF 5.[illegible] LBS/HR.
6. HELIUM SUPPLY - COMMERCIAL GRADE PURITY. CANISTER FLOW RATE IS NORMALLY ZERO; MES FLOW RATE IS 0.001 LBS/HR AT 80 AMPERE LOAD. CAVITY FILL RATE - SMALL NOMINAL FLOW REQUIRED ONLY AT SHUTDOWN.
7. VENT GRADUATE AND VACUUM VENT - VACUUM MUST BE LESS THAN 5 PSIA. VAPOR VENT VALVE WILL OPEN IF PRESSURE [illegible] EXCEEDS 5.5 PSIA AT PRESSURE SWITCH. VALVE MAY BE MANUALLY OPENED USING CONTROL SWITCH ON A-C CONTROL PANEL.

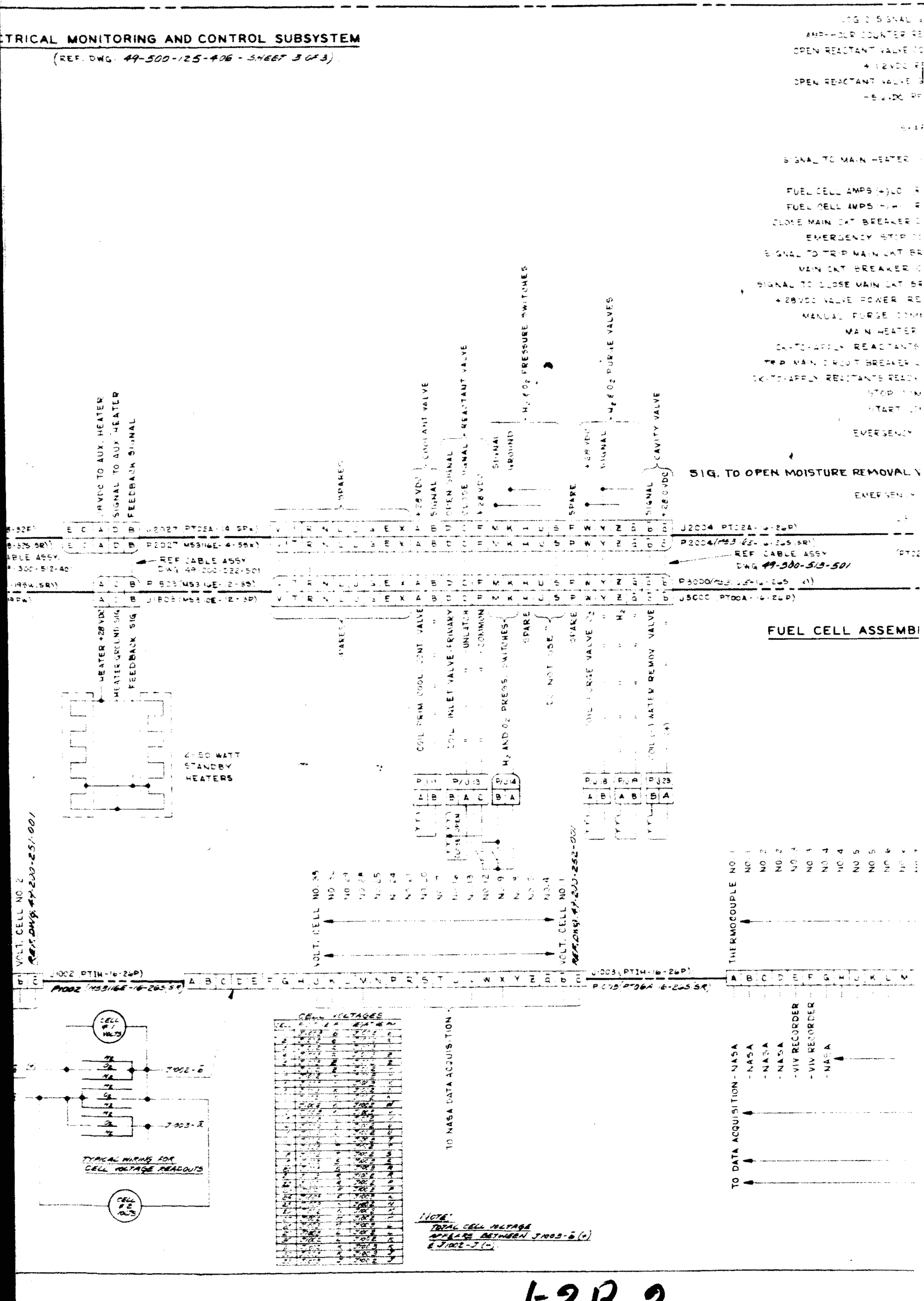
CONFIDENTIAL - PROPERTY OF ALLIS-CHALMERS MFG. CO.	INTERFACE SCHEMATIC SYS. #5R (FCA)
	FIGURE 1-2A
	49-500-25-404

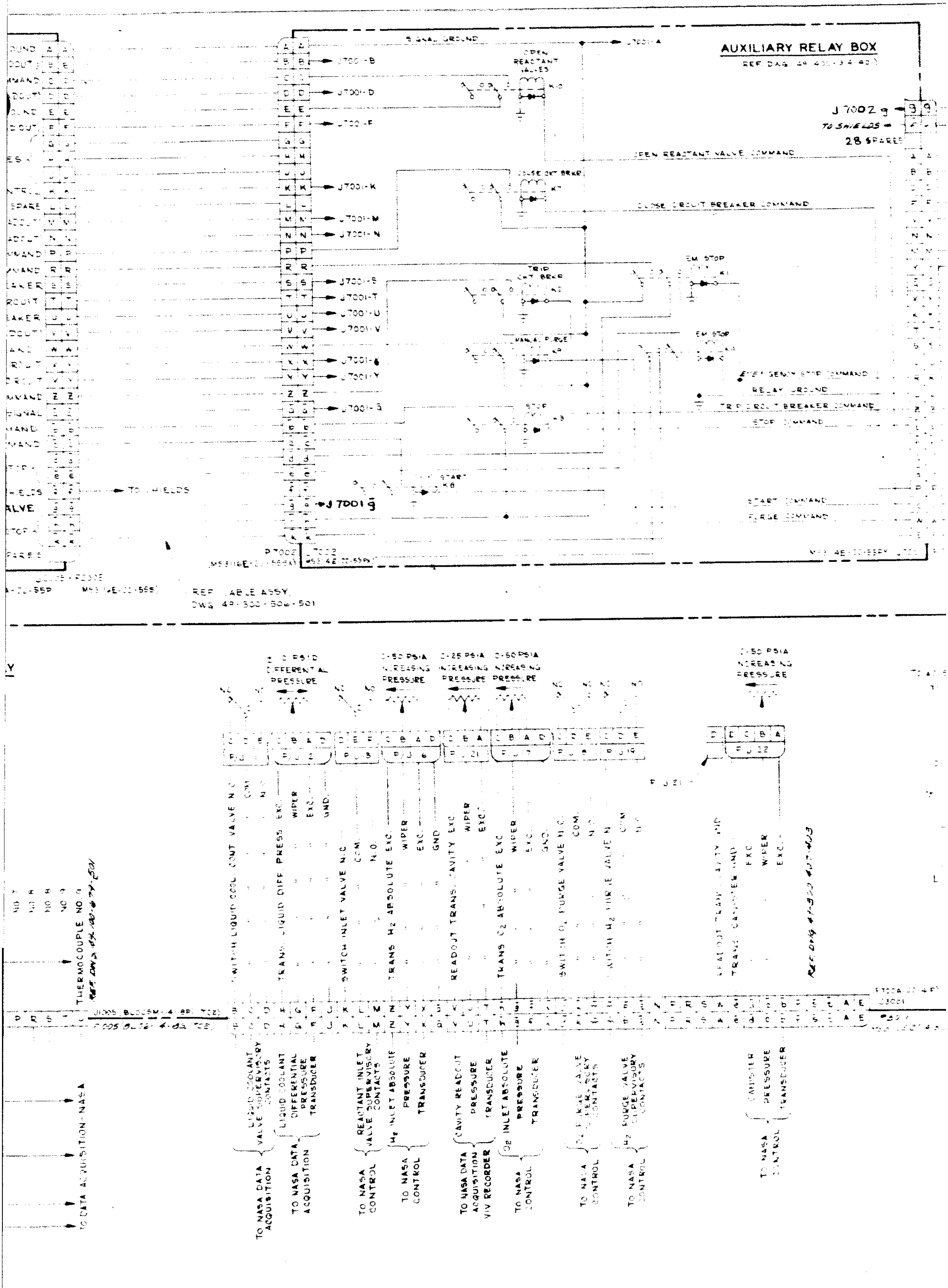
49-500-25-404


ELE
REF. CABLE ASSY.
DWG. 49-200-523-501
A-C CONTROL PANEL
P5004-A
P5004-B
P5004-C
P5004-D
P5004-E
+28 VDC FUEL CELL PWR
FCA & AUXILIARY GROUND
+28 VDC AUX. HEATER POWER
+28 VDC AUX. VALVE POWER
HEATER GROUND
(MS3116E-14-5S) P2003
J2003 (PT02A-14-5P)
SHIELDS
FCA SHUNT (+) LO PURGE
FCA SHUNT (-) HI PURGE
FCA SHUNT (+) LO AMPS READOUT
FCA SHUNT (-) HI AMPS READOUT
GND TO O.T. THERMOSTAT
O.T. THERMOSTAT SIGNAL
STANDBY HEATERS THERMOSTAT SIGNAL
GND TO STANDBY HEATER THERMOSTATS
SPARES
GND
SIGNAL
EXCITATION
SPARES
THERMISTOR #2 (SPARE)
THERMISTOR #1
TRANSISTOR #2 (SPARE)
TRANSISTOR #1
J2002
P2002
SHUNT CABINET
P5001-A
P5001-P
P5001-M
P5001-R
P3002
J3002
P1001
J1001
SPARES
GROUND TO CAVITY TRANSDUCER
CAVITY TRANSDUCER SIGNAL
CAVITY TRANSDUCER EXCITATION
SPARES
CELL 21
EMITTER
BASE
COLLECTOR
EMITTER
BASE
COLLECTOR
CELL 17
CELL 19
STANDBY HEATER THERMOSTATS
BOTH CLOSE AT 250°F
P/J 20
INCREASING PRESSURE 0-25 PSIA
(AC SIDE) FAN RPM SENSOR
(AC SIDE) FAN RPM SENSOR
(SHIELD)
(BD SIDE) FAN RPM SENSOR
(BD SIDE) FAN RPM SENSOR
(BD SIDE) FAN RPM (SHIELD)
(BD SIDE) FAN MOTOR
(BD SIDE) FAN MOTOR
(BD SIDE) FAN MOTOR
(BD SIDE) FAN MOTOR (SHIELD)
(AC SIDE) FAN MOTOR
(AC SIDE) FAN MOTOR
(AC SIDE) FAN MOTOR
(AC SIDE) FAN MOTOR (SHIELD)
VOLT. CELL NO. 44
NO. 41
NO. 30
NO. 27
NO. 19
NO. 18
NO. 15
NO. 14
NO. 11
NO. 10
J1000
P1000
TO NASA DATA ACQUISITION
TO NASA CONTROL
TO NASA DATA ACQUISITION

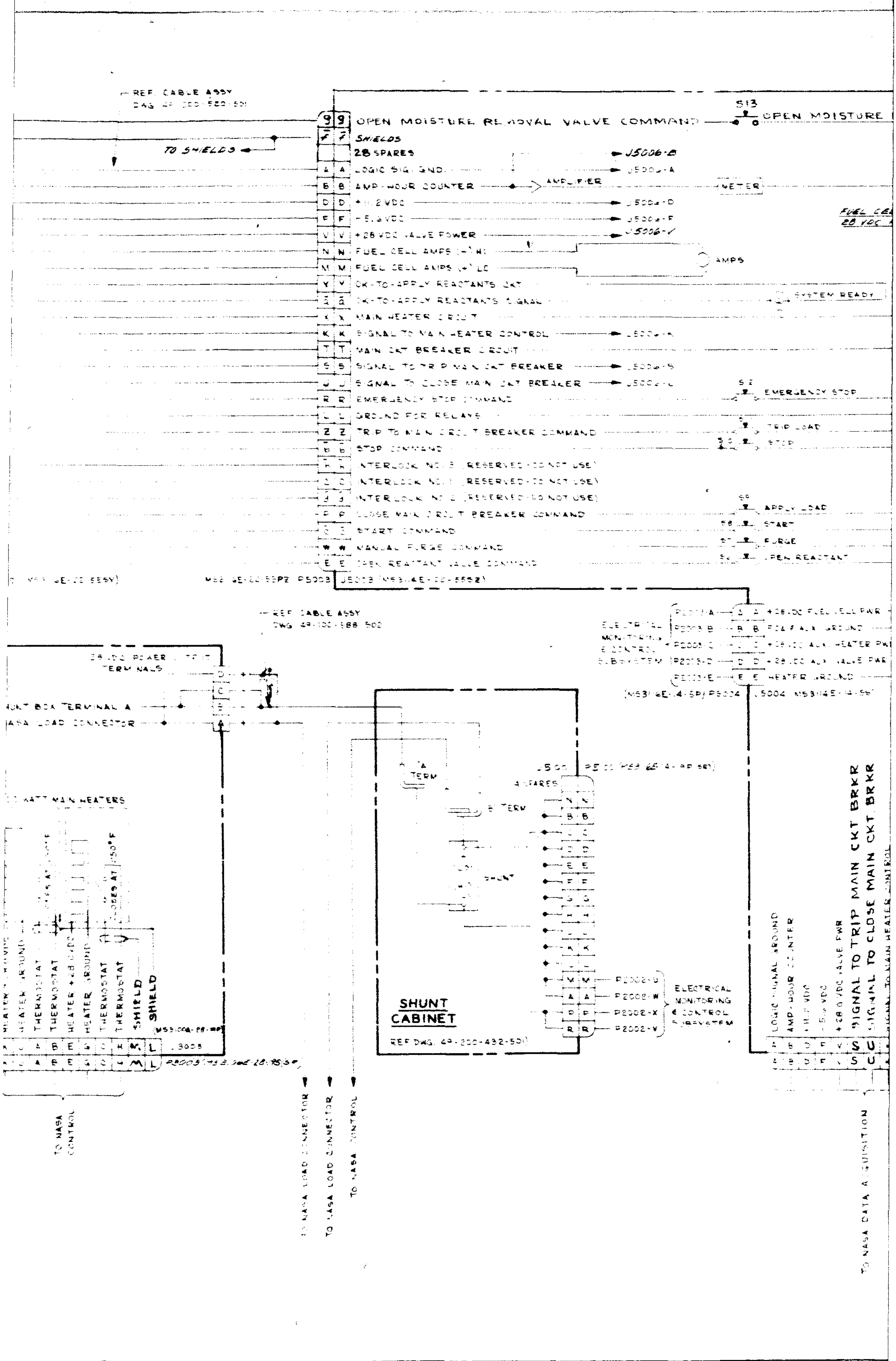
...TRICAL MONITORING AND CONTROL SUBSYSTEM

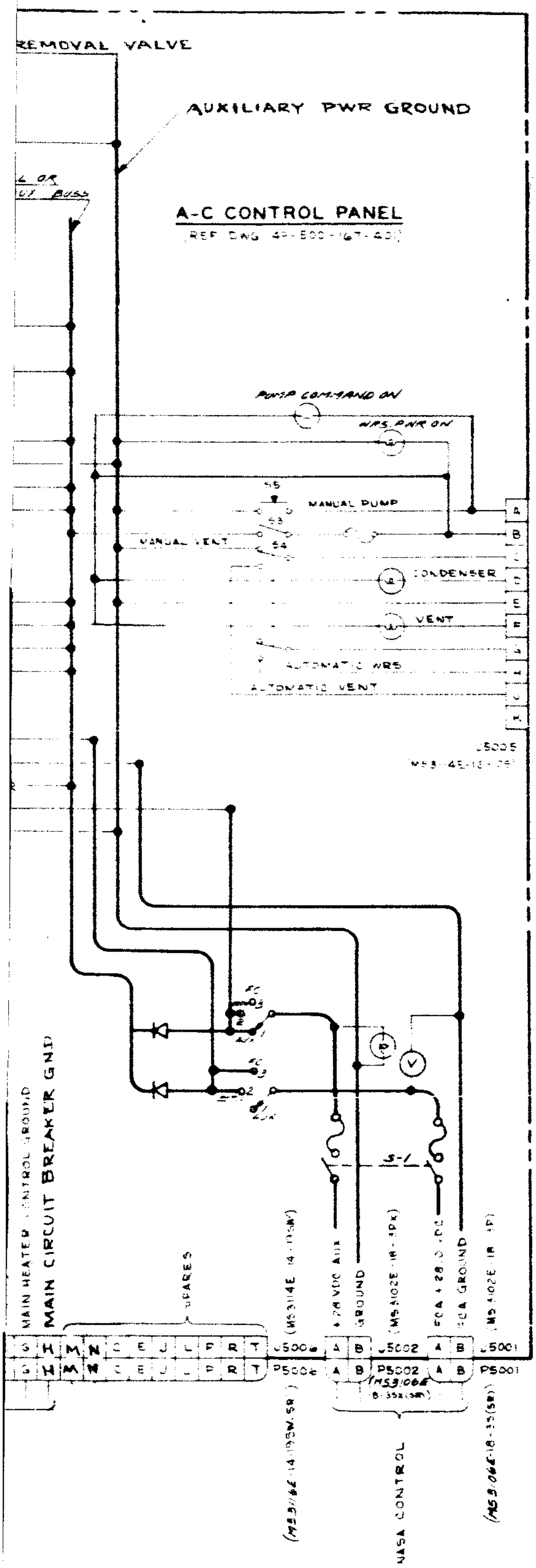
(REF. DWG. 49-500-125-406 - SHEET 3 OF 3)





AUXILIARY RELAY BOX
SIGNAL GROUND
J7001-A
J7001-B
J7001-D
J7001-F
J7001-K
J7001-M
J7001-N
J7001-S
J7001-T
J7001-U
J7001-V
J7001-Y
J7001 g
OPEN REACTANT VALVES
CLOSE CKT BRKR
TRIP CKT BRKR
MANUAL PURGE
EM STOP
STOP
START
J 7002 g
TO SHIELDS
28 SPARES
OPEN REACTANT VALVE COMMAND
CLOSE CIRCUIT BREAKER COMMAND
EMERGENCY STOP COMMAND
RELAY GROUND
TRIP CIRCUIT BREAKER COMMAND
STOP COMMAND
START COMMAND
PURGE COMMAND
TO SHIELDS
P7002
J7002
REF CABLE ASSY
DWG 4P-300-506-501
THERMOCOUPLE NO. 6
0-50 PSIA INCREASING PRESSURE
0-25 PSIA INCREASING PRESSURE
DIFFERENTIAL PRESSURE
SWITCH LIQUID COOL. CONT. VALVE N.C.
TRANS. LIQUID DIFF. PRESS.
SWITCH INLET VALVE N.C.
TRANS. H_2 ABSOLUTE
READOUT TRANS. CAVITY
TRANS. O_2 ABSOLUTE
SWITCH O_2 PURGE VALVE N.C.
EXC.
WIPER
GND.
COM.
N.O.
LIQUID COOLANT VALVE SUPERVISORY CONTACTS
LIQUID COOLANT DIFFERENTIAL PRESSURE TRANSDUCER
REACTANT INLET VALVE SUPERVISORY CONTACTS
H_2 INLET ABSOLUTE PRESSURE TRANSDUCER
CAVITY READOUT PRESSURE TRANSDUCER
O_2 INLET ABSOLUTE PRESSURE TRANSDUCER
H_2 PURGE VALVE SUPERVISORY CONTACTS
CANISTER PRESSURE TRANSDUCER
TO NASA DATA ACQUISITION
TO NASA CONTROL
TO NASA DATA ACQUISITION VIV RECORDER
TO DATA ACQUISITION-NASA


REF CABLE ASSY
TO SHIELDS
OPEN MOISTURE REMOVAL VALVE COMMAND
S13
OPEN MOISTURE
SHIELDS
28 SPARES
J5006-B
LOGIC SIG. GND.
AMP-HOUR COUNTER
AMPLIFIER
METER
+28 VDC VALVE POWER
J5006-V
FUEL CELL AMPS
AMPS
OK-TO-APPLY REACTANTS CKT
SYSTEM READY
MAIN HEATER CIRCUIT
SIGNAL TO MAIN HEATER CONTROL
MAIN CKT BREAKER CIRCUIT
SIGNAL TO TRIP MAIN CKT BREAKER
SIGNAL TO CLOSE MAIN CKT BREAKER
EMERGENCY STOP COMMAND
EMERGENCY STOP
GROUND FOR RELAYS
TRIP TO MAIN CIRCUIT BREAKER COMMAND
TRIP LOAD
STOP COMMAND
STOP
INTERLOCK NO. 3 (RESERVED-DO NOT USE)
INTERLOCK NO. 1 (RESERVED-DO NOT USE)
INTERLOCK NO. 2 (RESERVED-DO NOT USE)
CLOSE MAIN CIRCUIT BREAKER COMMAND
APPLY LOAD
START COMMAND
START
MANUAL PURGE COMMAND
PURGE
OPEN REACTANT VALVE COMMAND
OPEN REACTANT
P5003
J5003
REF CABLE ASSY
ELECTRICAL MONITORING & CONTROL SUBSYSTEM
P5004
J5004
HEATER GROUND
28 VDC POWER OUTPUT TERMINALS
SHUNT BOX TERMINAL A
NASA LOAD CONNECTOR
WATT MAIN HEATERS
THERMOSTAT
THERMOSTAT
HEATER +28 VDC
HEATER GROUND
THERMOSTAT
THERMOSTAT
SHIELD
SHIELD
J3005
P3005
TERM
SHUNT
4 SPARES
P2002-U
P2002-W
P2002-X
P2002-Y
ELECTRICAL MONITORING & CONTROL SUBSYSTEM
SHUNT CABINET
REF DWG. 49-200-432-501
SIGNAL TO TRIP MAIN CKT BRKR
SIGNAL TO CLOSE MAIN CKT BRKR
TO NASA CONTROL
TO NASA LOAD CONNECTOR
TO NASA LOAD CONNECTOR
TO NASA CONTROL
TO NASA DATA ACQUISITION



C1 3-22-66

ON AC CONTROL PANEL
REMOVED WIRES CONNECT
J5003N TO J5006N
J5003M TO J5006M.
ADDED 9 TO P/J5003
FOLLOWING LAMPS –
PUMP COMMAND ON
CONDENSER
VENT
ALL HAD BEEN
CONNECTED DIRECTLY
TO FUEL CELL OR
28 V.DC AUX. BUSS
INSTEAD OF THRU
S3 AND FUSE.
SYSTEM READY LIGHT
DISCONNECTED FROM
FUEL CELL OR 28 V.D.C
AUX. BUS AND AUX.
POWER GROUND.

ON FUEL CELL ASSEMBLY
TERMINAL M AND L
ADDED TO J3003
ALONG WITH SHIELDS

02 6-3-66

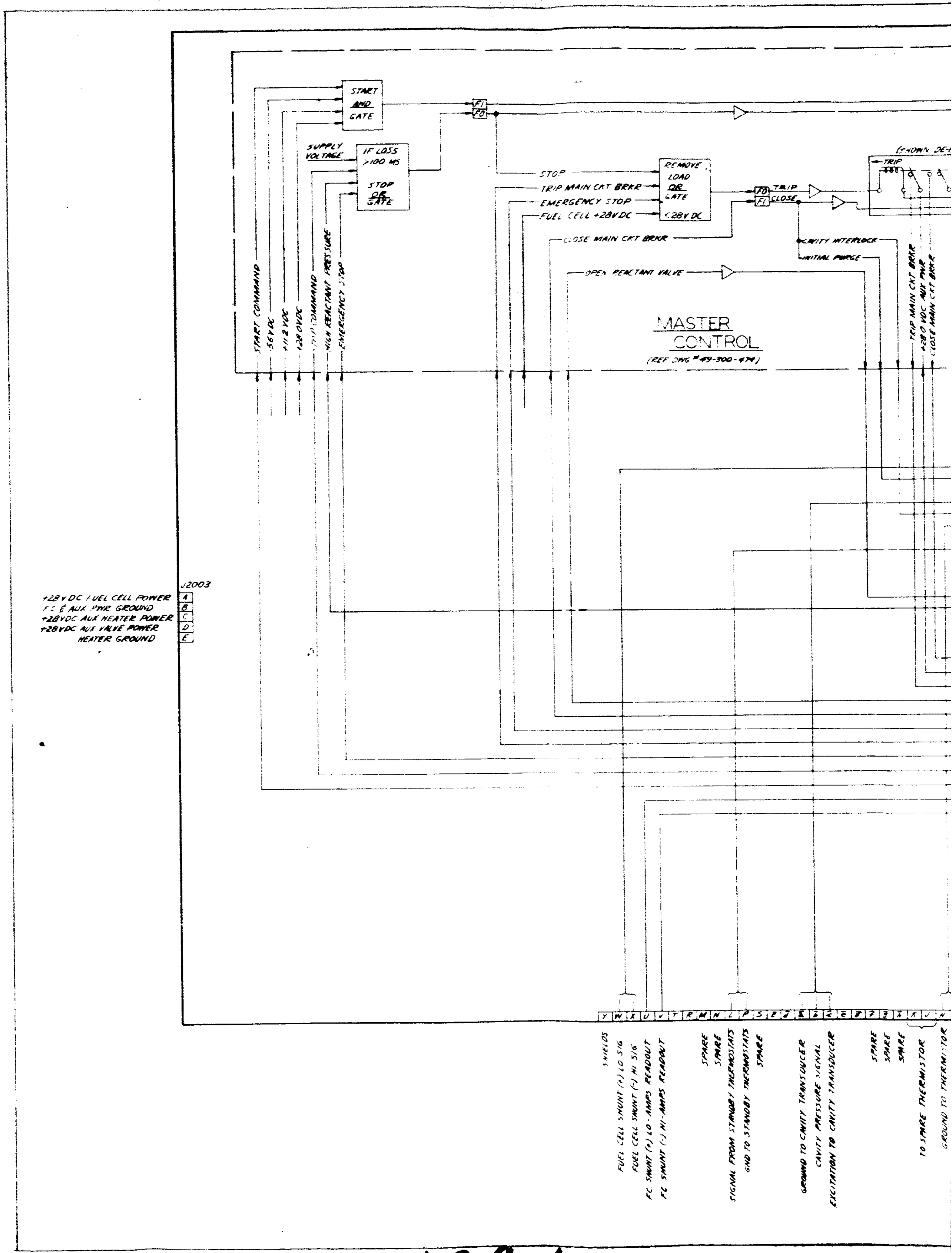
REDUCED REPRODUCTION OF 49-500-125-404 SHEET 2 OF 3

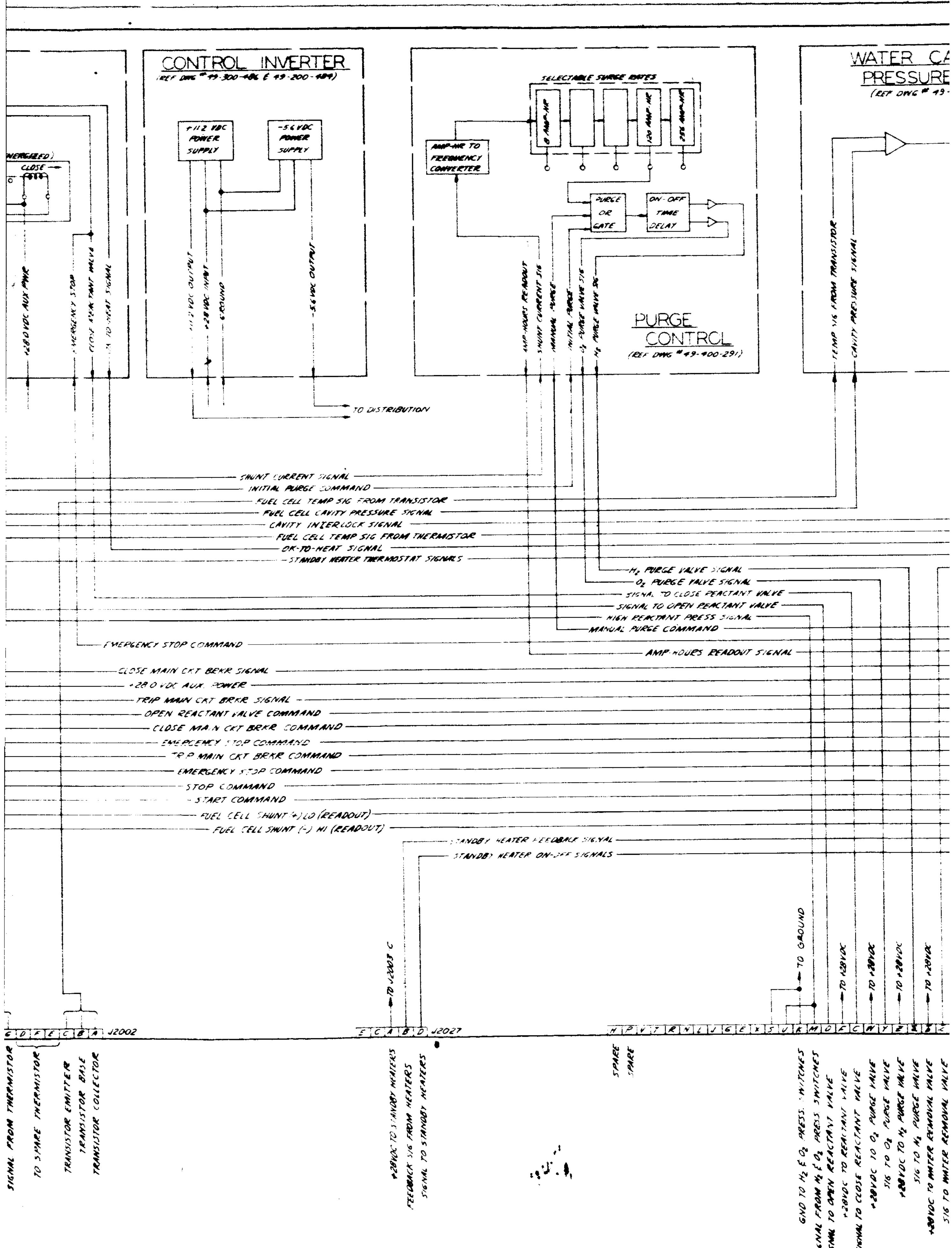
ALLIS-CHALMERS MFG CO
3341 M.I.

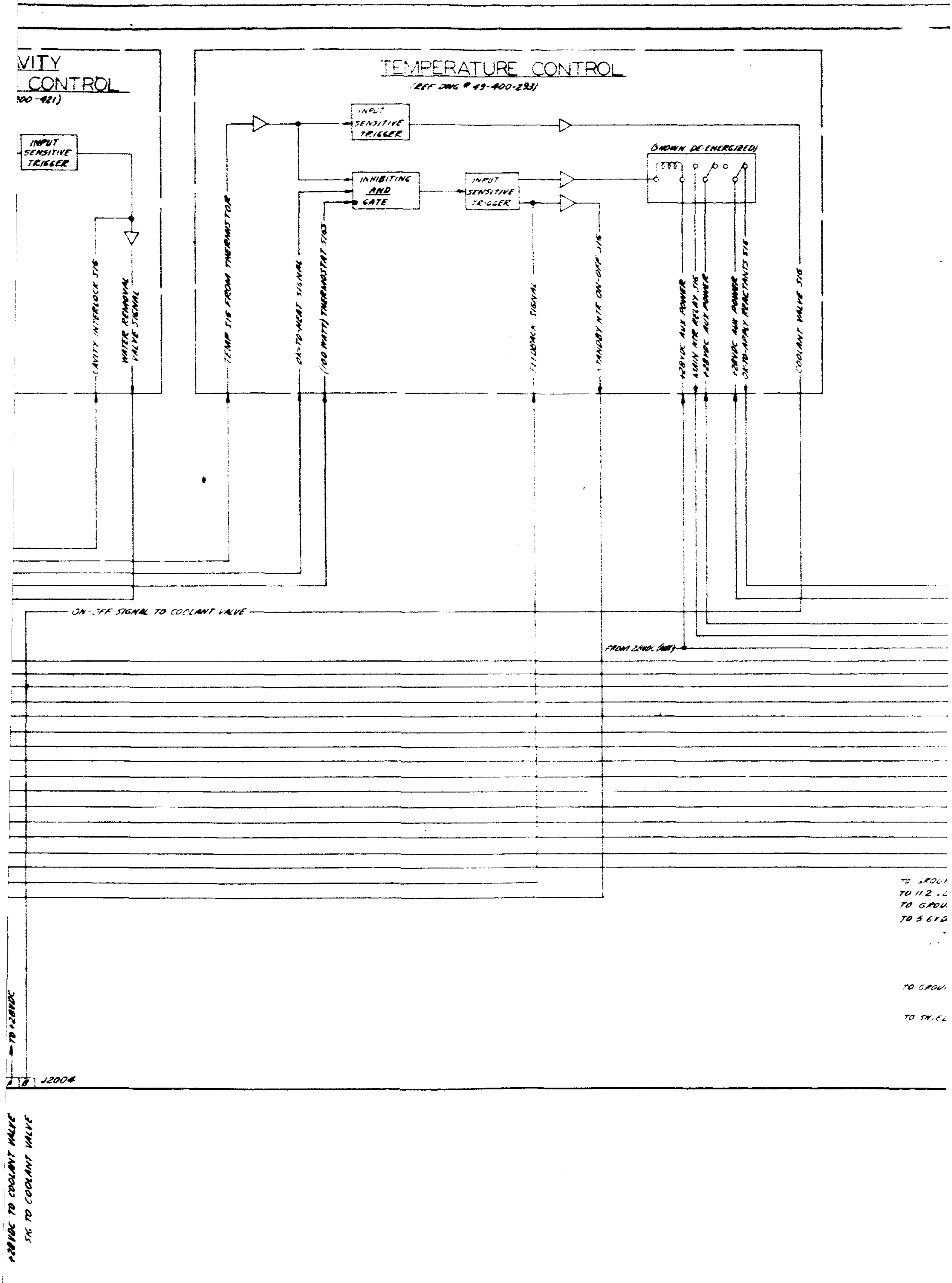
FUEL CELL SYSTEM-SR
INTERFACE SCHEMATIC

2 of 3

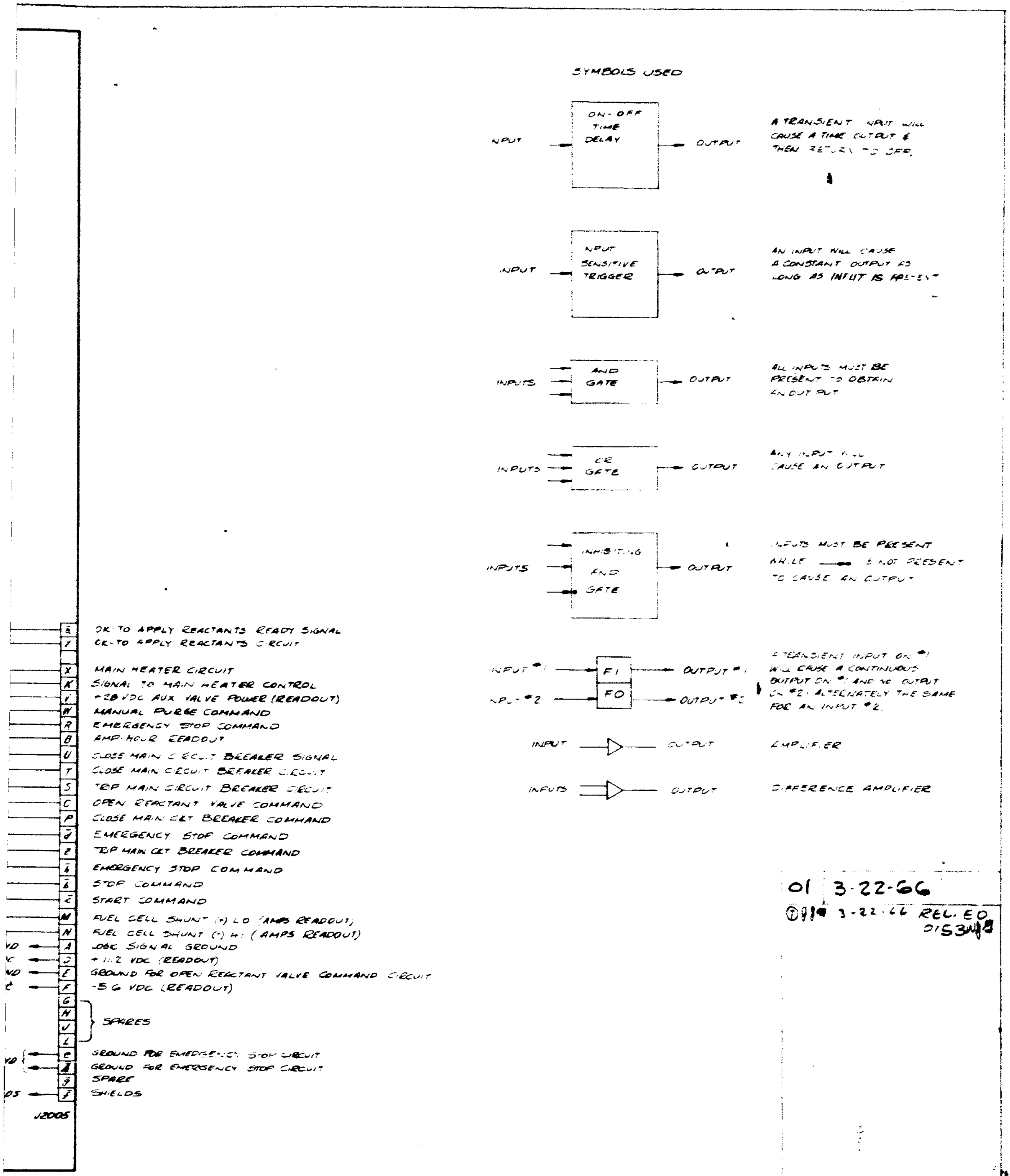
FIG 1-2B


START
AND
GATE
SUPPLY VOLTAGE
IF LOSS >100 MS
STOP
OR
GATE
STOP
TRIP MAIN CKT BRKR
EMERGENCY STOP
FUEL CELL +28VDC
REMOVE LOAD
OR
GATE
<28V DC
FI
FO
TRIP
CLOSE
CLOSE MAIN CKT BRKR
OPEN REACTANT VALVE
CAVITY INTERLOCK
INITIAL PURGE
(SHOWN DE-
START COMMAND
56VDC
+11.2VDC
+28.0VDC
STOP COMMAND
HIGH REACTANT PRESSURE
EMERGENCY STOP
TRIP MAIN CKT BRKR
+28.0VDC AUX PWR
CLOSE MAIN CKT BRKR
MASTER CONTROL
(REF DWG #49-300-474)
J2003
+28VDC FUEL CELL POWER A
FC & AUX PWR GROUND B
+28VDC AUX HEATER POWER C
+28VDC AUX VALVE POWER D
HEATER GROUND E
Y W X U V T R M N L P S
SHIELDS
FUEL CELL SHUNT (+) LO SIG
FUEL CELL SHUNT (-) HI SIG
FC SHUNT (+) LO-AMPS READOUT
FC SHUNT (-) HI-AMPS READOUT
SPARE
SPARE
SIGNAL FROM STANDBY THERMOSTATS
GND TO STANDBY THERMOSTATS
SPARE
GROUND TO CAVITY TRANSDUCER
CAVITY PRESSURE SIGNAL
EXCITATION TO CAVITY TRANSDUCER
SPARE
SPARE
SPARE
TO SPARE THERMISTOR
GROUND TO THERMISTOR


CONTROL INVERTER
(REF DWG # 49-300-486 & 49-200-489)
+112 VDC POWER SUPPLY
-56 VDC POWER SUPPLY
+112 VDC OUTPUT
+28 VDC INPUT
GROUND
-56 VDC OUTPUT
TO DISTRIBUTION
CLOSE
+28.0 VDC AUX PWR
EMERGENCY STOP
CLOSE REACTANT VALVE
OK TO HEAT SIGNAL
SELECTABLE SURGE RATES
8 AMP-HR
120 AMP-HR
256 AMP-HR
AMP-HR TO FREQUENCY CONVERTER
PURGE OR GATE
ON-OFF TIME DELAY
AMP-HOURS READOUT
SHUNT CURRENT SIG
MANUAL PURGE
INITIAL PURGE
O_2 PURGE VALVE SIG
H_2 PURGE VALVE SIG
PURGE CONTROL
(REF DWG # 49-400-291)
WATER CA
PRESSURE
(REF DWG # 49-
TEMP SIG FROM TRANSISTOR
CAVITY PRESSURE SIGNAL
SHUNT CURRENT SIGNAL
INITIAL PURGE COMMAND
FUEL CELL TEMP SIG FROM TRANSISTOR
FUEL CELL CAVITY PRESSURE SIGNAL
CAVITY INTERLOCK SIGNAL
FUEL CELL TEMP SIG FROM THERMISTOR
OK-TO-HEAT SIGNAL
STANDBY HEATER THERMOSTAT SIGNALS
H_2 PURGE VALVE SIGNAL
O_2 PURGE VALVE SIGNAL
SIGNAL TO CLOSE REACTANT VALVE
SIGNAL TO OPEN REACTANT VALVE
HIGH REACTANT PRESS SIGNAL
MANUAL PURGE COMMAND
EMERGENCY STOP COMMAND
AMP-HOURS READOUT SIGNAL
CLOSE MAIN CKT BRKR SIGNAL
+28.0 VDC AUX. POWER
TRIP MAIN CKT BRKR SIGNAL
OPEN REACTANT VALVE COMMAND
CLOSE MAIN CKT BRKR COMMAND
EMERGENCY STOP COMMAND
TRIP MAIN CKT BRKR COMMAND
EMERGENCY STOP COMMAND
STOP COMMAND
START COMMAND
FUEL CELL SHUNT (+) LO (READOUT)
FUEL CELL SHUNT (-) HI (READOUT)
STANDBY HEATER FEEDBACK SIGNAL
STANDBY HEATER ON-OFF SIGNALS
TO J2003 C
TO GROUND
TO +28VDC
TO +28VDC
TO +28VDC
TO +28VDC
G D F E C B A J2002
E C A B D J2027
H P V T R N L J G E X S U K M D F C W Y Z
SIGNAL FROM THERMISTOR
TO SPARE THERMISTOR
TRANSISTOR EMITTER
TRANSISTOR BASE
TRANSISTOR COLLECTOR
+28VDC TO STANDBY HEATERS
FEEDBACK SIG FROM HEATERS
SIGNAL TO STANDBY HEATERS
SPARE
SPARE
GND TO H_2 & O_2 PRESS. SWITCHES
SIGNAL FROM H_2 & O_2 PRESS SWITCHES
SIGNAL TO OPEN REACTANT VALVE
+28VDC TO REACTANT VALVE
SIGNAL TO CLOSE REACTANT VALVE
+28VDC TO O_2 PURGE VALVE
SIG TO O_2 PURGE VALVE
+28VDC TO H_2 PURGE VALVE
SIG TO H_2 PURGE VALVE
+28VDC TO WATER REMOVAL VALVE
SIG TO WATER REMOVAL VALVE



VITY
CONTROL
TEMPERATURE CONTROL
(REF DWG # 49-400-293)
INPUT SENSITIVE TRIGGER
INHIBITING AND GATE
INPUT SENSITIVE TRIGGER
(SHOWN DE-ENERGIZED)
CAVITY INTERLOCK SIG
WATER REMOVAL VALVE SIGNAL
TEMP SIG FROM THERMISTOR
OK-TO-HEAT SIGNAL
(100 WATT) THERMOSTAT SIGS
FEEDBACK SIGNAL
STANDBY HTR ON-OFF SIG
+28VDC AUX POWER
MAIN HTR RELAY SIG
+28VDC AUX POWER
+28VDC AUX POWER
OK-TO-APPLY REACTANTS SIG
COOLANT VALVE SIG
ON-OFF SIGNAL TO COOLANT VALVE
TO +28VDC
J2004
+28VDC TO COOLANT VALVE
SIG TO COOLANT VALVE



REDUCED REPRODUCTION
OF 49-500-125-404
SHEET 3 OF 3

ALLIS-CHALMERS MFG. CO.

SYSTEM SR INTERFACE SCHEMATIC EMCS LOGIC DIAGRAM

FIG. 1-2C

1-20-D

SECTION II

INSTALLATION INSTRUCTIONS

2.1 UNPACKING, INSPECTION AND ASSEMBLY

2.1.1 Shipping Containers

The fuel cell module including the reactant control valve assembly will be shipped within a wooden container as shown in Figure 2-1 (drawing No. 49-400-230-401). The fuel cell module has been pressurized with helium to a pressure of approximately 5 psig and appropriate care should be exercized in handling the unit. The shipping container should be placed in the proper vertical attitude to facilitate cell removal.

The fuel cell module should be supported from the eyelets provided in the upper clamp-ring shim,and then it may be unbolted from the shipping container and moved to the test area.

The other items supplied by Allis-Chalmers for the assembly of Fuel Cell System #5R will be boxed in wood and/or cardboard containers suitably protected against moisture and dirt.

2.1.2 Inspection Prior to Assembly

All major components have been cleaned and packaged at the Allis-Chalmers facility, however, prior to assembly all components should be examined for cleanliness.

2.1.3 Assembly of the Fuel Cell System

Fuel Cell System #5R as delivered consists of five major subassemblies to which interconnections must be made in the field. Refer to Figure 2-2A (Drawing No. 49-400-230-405 and Figure 2-2B (Drawing No. 49-200-431-504.

These figures physically locate each point of interconnection, identify the interconnecting cable, show the connector designation and specify the customer tie-in points. The major subassemblies are:

Item 2	Fuel Cell Module whose Major Subassemblies are Stack the Fuel Cell and the Reactant Control Subsystem.
Item 4	Electrical Monitoring and Control Subsystem.
Item 5	Current Shunt Cabinet
Item 6	Allis-Chalmers Auxiliary Relay Box (For reference only)
Item 7	Allis-Chalmers Control Panel (For reference only)

Allis-Chalmers has furnished interconnecting electrical cables between the fuel cell module and the EMCS, the module and the shunt cabinet and a "Y" cable from the EMCS to the shunt cabinet and from the EMCS to the fuel cell module.

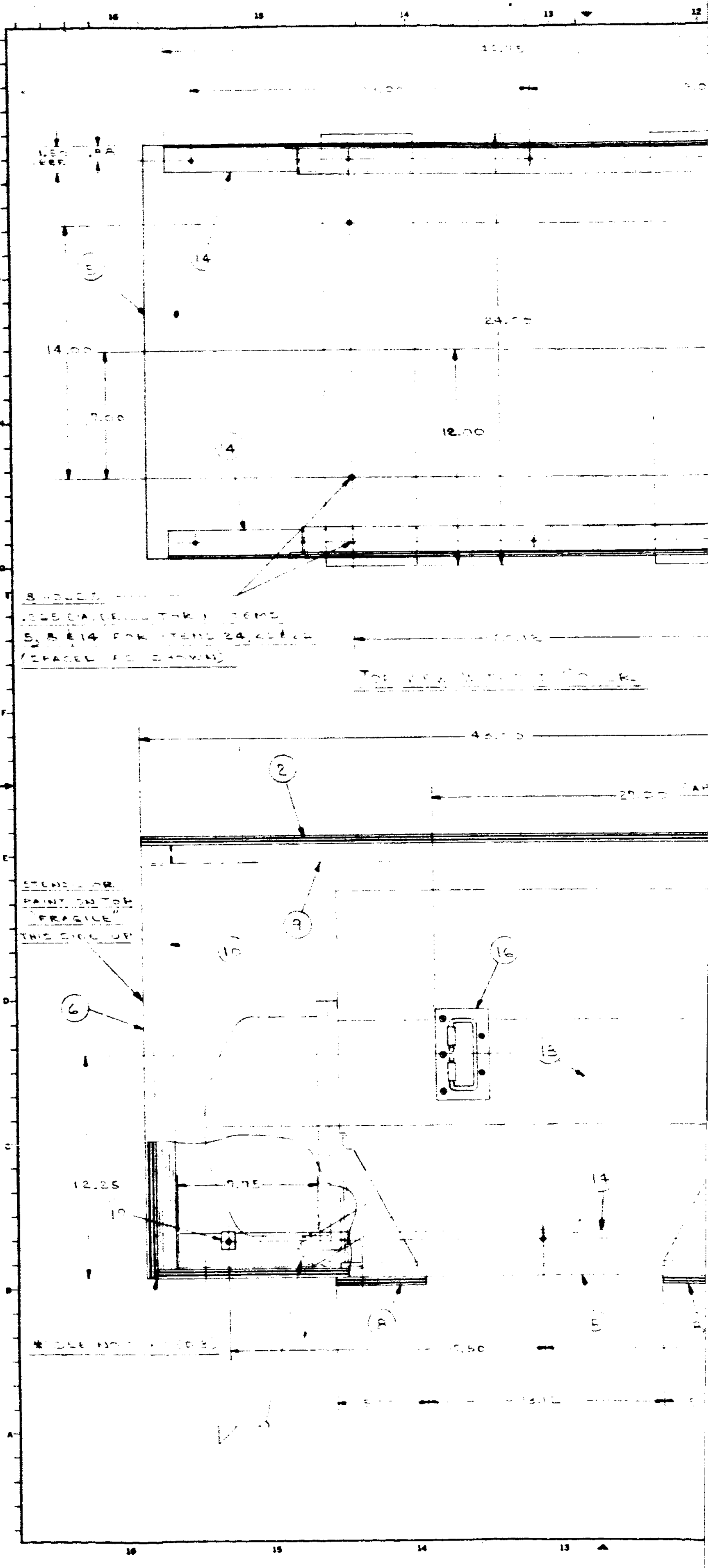
In addition, Allis-Chalmers has furnished all mating connectors for the remaining electrical connectors and all pneumatic/hydraulic fittings for use on the A-C furnished equipments.

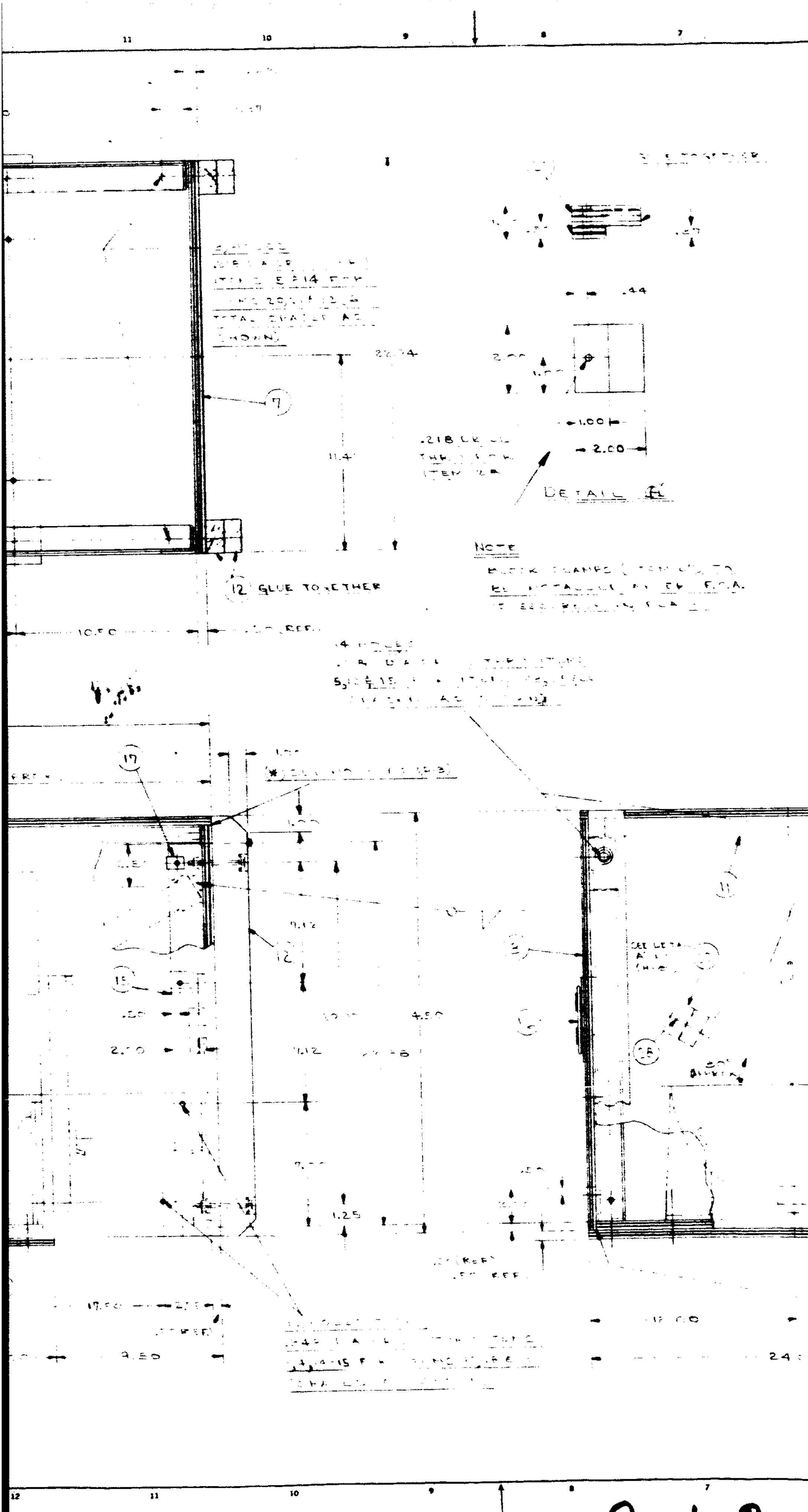
2.1.4 Equipment Furnished by the Marshall Space Flight Center

MSFC will furnish the following major items for the test setup of System #5R.

A. All operational controls including switches and indicators. Figure 2-3 contains a listing of the recommended controls and indicators for operation of the test setup. Figure 2-4A (Dwg. No. 49-200-550-501),
Figure 2-4B (Dwg. No. 49-400-318-401),
Figure 2-4C (Dwg. No. 49-400-314-401),
Figure 2-5 (Dwg. No. 49-200-523-501),
Figure 2-6 (Dwg. No. 49-300-506-501),
Figure 2-7 (Dwg. No. 49-300-520-501), &
Figure 3-4 (Dwg. No. 49-400-349-402)
contain additional information on the method of control and indicator hookup.

B. All tubing, valves, gases, and flowmeters required to bring the reactant gases, helium gas and the liquid coolant to the fuel cell interface and to handle the by-product water. Figure 1-2A (Dwg. No. 49-500-125-404).


14
12.00
2
9
16
6
12.25
14

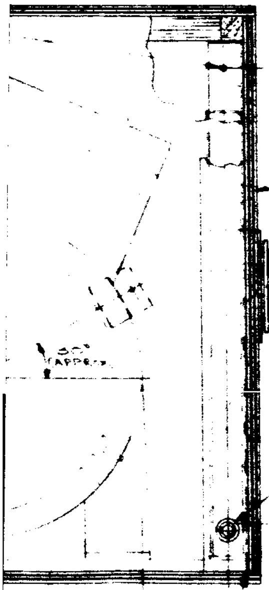


.44
2.00
1.00
2.00
.218
DETAIL A
NOTE
12 GLUE TOGETHER
10.50
17
15
12
4.50
1.25
9.50

9-1-2

01	8-4-65	RBM

REQ.	ITEM	DESCRIPTION	MATERIAL	PART NO.
	1	[illegible]		49-400-230-501
1	2	.50 x 24.00 x 42.00 LG PANEL	[illegible]	[illegible]-002
1	3	" x "	"	-003
1	4	" x "	"	-004
1	5	x 22.74 x 41.00	"	-005
1	6	x 23.00 x 24.00		-006
1	7	x 22.74 x 24.00		-007
2	8	" x [illegible] x 25.00		-008
2	9	[illegible] 40.75 LG [illegible]	[illegible]	-009
2	10	" x " 25 "	"	-010
1	11	" x " x 22.75 "	"	-011
4	12	2.00 x 4.00 x 24.00 LG SKID	"	-012
2	13	.50 x .50 x 38.25 LG ANGLE	STD STRUCTURAL ALUMINUM	00-591-108-271
2	14	2.00 x 1.50 x .125 THK ANGLE MF 3.63 x 41.00 PLATE	ALUMINUM SHEET	00-591-406-128
2	15	" x " x " " MF 3.63 x 22.50 PLATE	"	00-591-406-125
2	16	CHEST HANDLE - MCMASTER-CARR SUPPLY CO. [illegible] 1264 - BLK FINISH	WROUGHT STEEL	49-400-230-016
12	17	RETAINER FOR SQUARE NUT	SPRING STEEL	00-693-351-120
12	18	.312-18 X 1.125 LG CAP SCREW	STEEL	" -671-289-423
12	19	.344 I.D. x .688 O.D. x .062 THK WASHER	STL ZINC PLATED	" -651-007-198
6	20	*10-24 x 1.00 LG RD HD MACH SCREW	"	" -615-471-225
6	21	*10-24 HEX NUT	"	" -631-109-110
6	22	.219 I.D. x .500 O.D. x .049 THK. WASHER	"	" -651-007-102
4	23	.250-20 x 2.75 LG HEX HD CAP SCREW		" -611-289-392
8	24	.250-20 x 2.25 "	"	" -398
12	25	.250-20 HVY S.F. HEX NUT		" -631-059-104
12	26	.281 I.D. x .625 O.D. x .062 THK WASHER	"	" -651-007-146
6	27	.50 x [illegible] x 3.50 CLAMP	EXTERIOR PLYWOOD	49-400-230-027
8	28	*10 x 1.50 LG FL HD WOOD SCREW	STEEL BLUED	00-617-321-229



NOTES:

1. GLUE & NAIL ALL WOOD JOINTS, (EXCEPT THOSE INDICATED THUS *) ITEM 8 TO ITEM 5 & SKIDS TO PANEL.
2. PAINT BOX WITH GRAY OR BLUE ENAMEL.
3. USE ANGLE FRAMES AS DRILLING TEMPLATE FOR HOLES IN PANELS.

1.00 DIA RECESS x .50 DEEP IN ITEM 12 FOR ITEM 25 CLEARANCE (4 PLACES)

(*) SEE NOTE 1 AT (D-3)

CONFIDENTIAL – PROPERTY OF
ALLIS-CHALMERS MFG. CO.
WEST ALLIS WORKS

NAME: SHIPPING CONTAINER FUEL CELL

MATL

UNLESS OTHERWISE SPECIFIED
1-PLACE DEC ±
2-PLACE DEC ±
3-PLACE DEC ±
ANGULAR ±

MACHINED SURFACE TEXTURE

WT R F

DR RER 8-2-65
CH PLS 8-4-65
AP RBM 8/4/65

SIMILAR TO

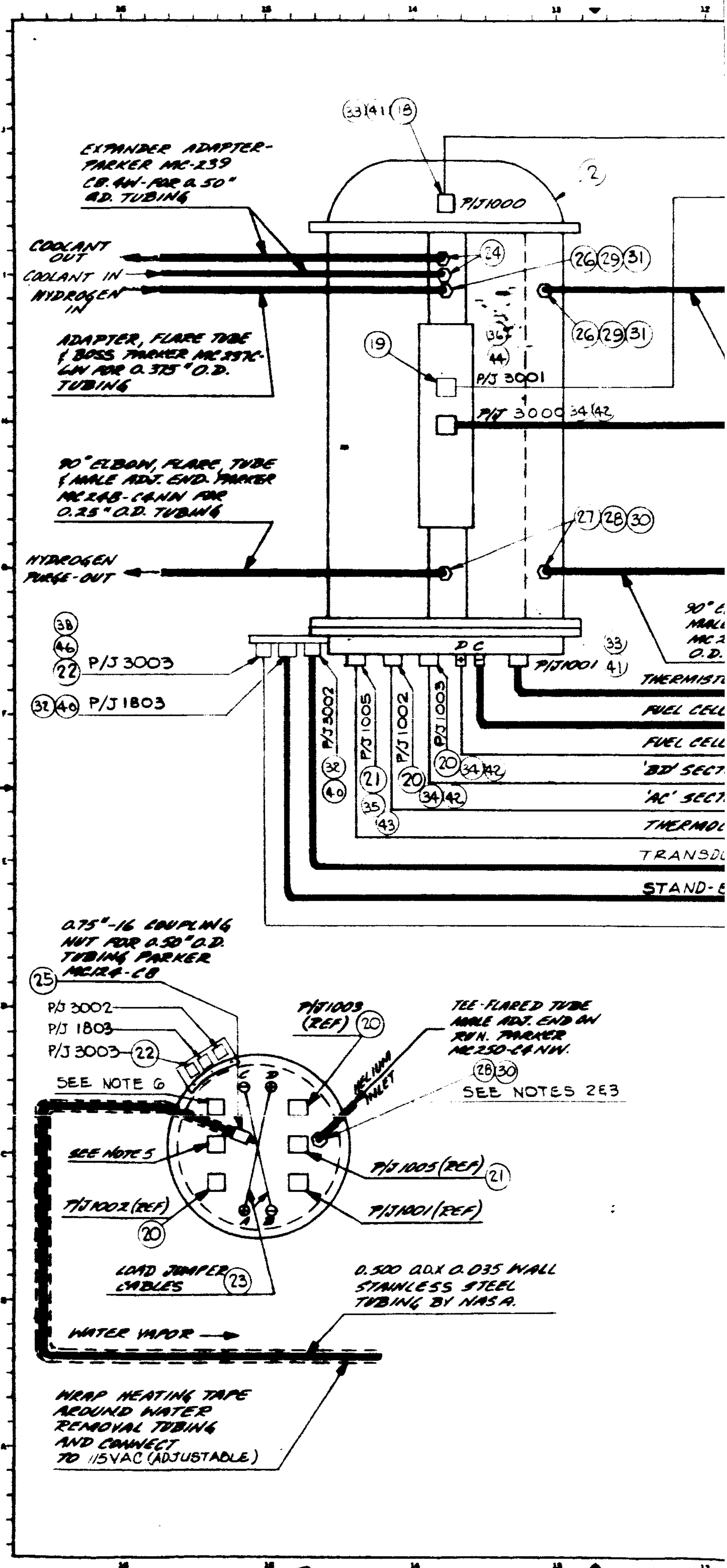
SCALE 3"=12"
SHEET

PART NO 49-400-230-501

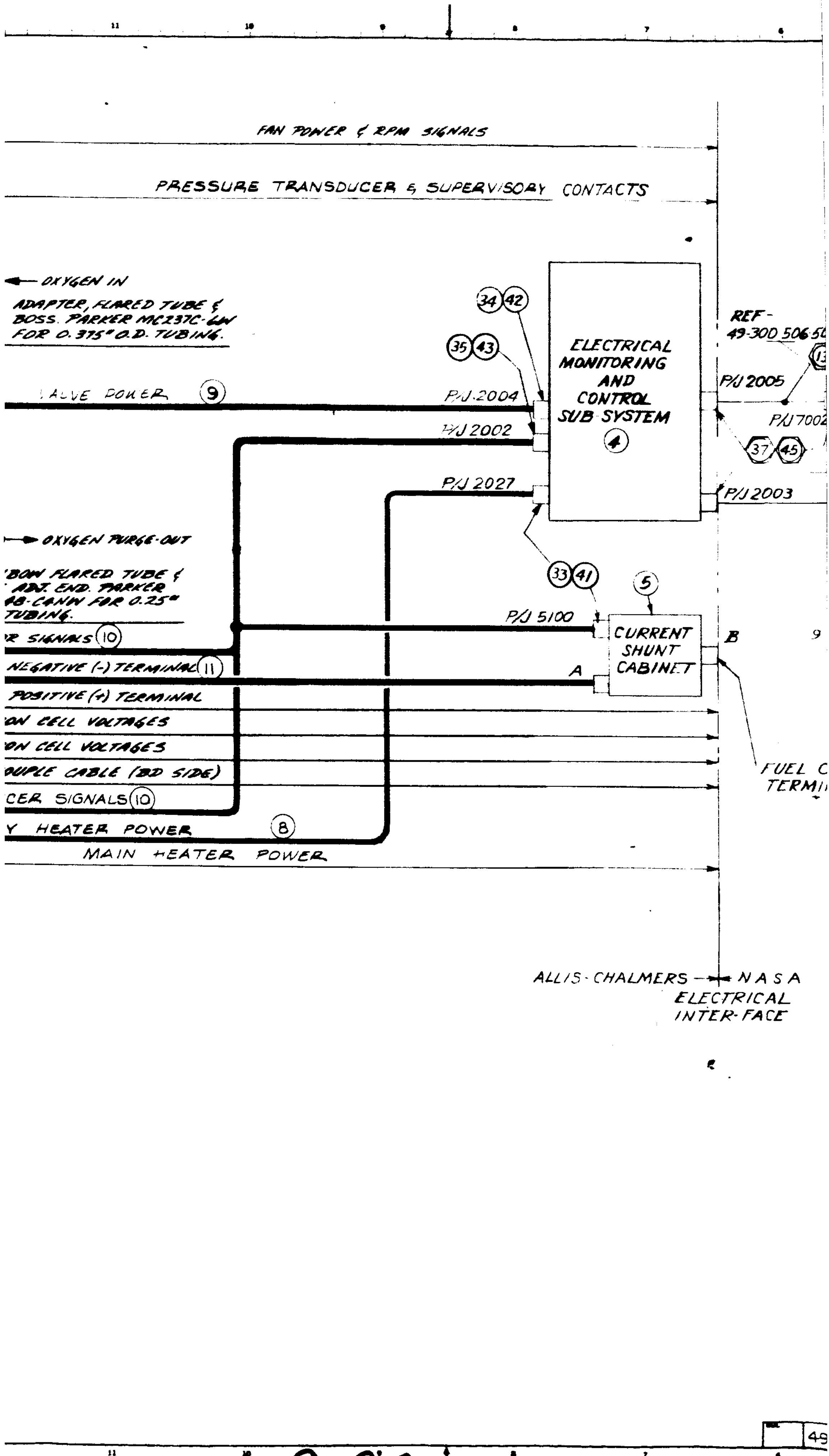
DWG 49-400-230 ISSUE 01

PRINTED IN U.S.A. FORM No. [illegible]

FIGURE 2-1-3

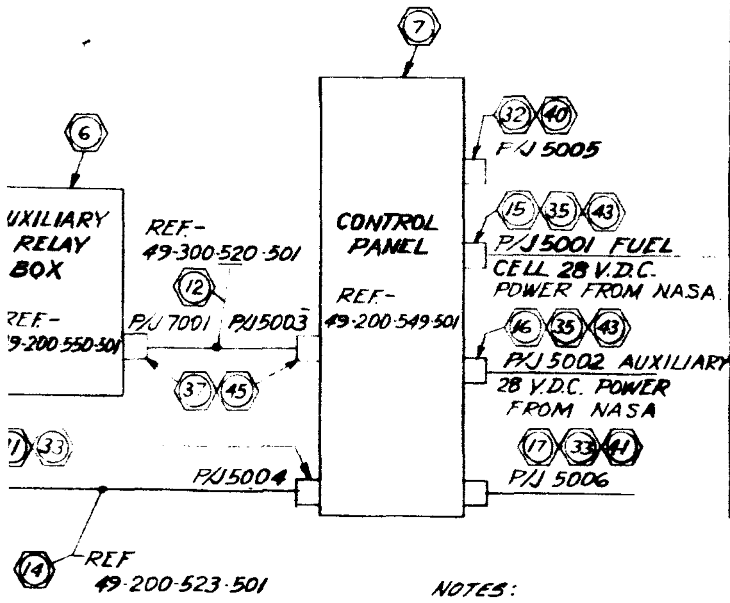


EXPANDER ADAPTER-PARKER MC-239 CB-4W-FOR 0.50" O.D. TUBING
COOLANT OUT
COOLANT IN
HYDROGEN IN
ADAPTER, FLARE TUBE & BOSS PARKER MC 237C-6W FOR 0.375" O.D. TUBING
90° ELBOW, FLARE, TUBE & MALE ADJ. END. PARKER MC248-C4NN FOR 0.25" O.D. TUBING
HYDROGEN PURGE-OUT
P/J1000
P/J 3001
P/J 3000
P/J 3003
P/J 1803
P/J1001
P/J3002
P/J1005
P/J1002
P/J1003
THERMIST
FUEL CELL
FUEL CELL
'BD' SECT
'AC' SECT
THERMOC
TRANSDU
STAND-
0.75"-16 COUPLING NUT FOR 0.50" O.D. TUBING PARKER MC124-C8
P/J 3002
P/J 1803
P/J 3003
SEE NOTE 6
P/J1003 (REF)
TEE-FLARED TUBE MALE ADJ. END ON RUN. PARKER MC250-C4NW.
SEE NOTES 2&3
HELIUM INLET
SEE NOTE 5
P/J1005 (REF)
P/J1002 (REF)
P/J1001 (REF)
LOAD JUMPER CABLES
0.500 O.D. X 0.035 WALL STAINLESS STEEL TUBING BY NASA.
WATER VAPOR
WRAP HEATING TAPE AROUND WATER REMOVAL TUBING AND CONNECT TO 115VAC (ADJUSTABLE)



FAN POWER & RPM SIGNALS
PRESSURE TRANSDUCER & SUPERVISORY CONTACTS
OXYGEN IN
ADAPTER, FLARED TUBE & BOSS. PARKER MC237C-6W FOR 0.375" O.D. TUBING.
34 42
35 43
ELECTRICAL MONITORING AND CONTROL SUB SYSTEM
4
REF - 49-300 506
P/J 2005
VALVE POWER 9
P/J 2004
P/J 2002
P/J 7002
37 45
P/J 2027
P/J 2003
OXYGEN PURGE-OUT
ELBOW FLARED TUBE & ADJ. END. PARKER
TUBING.
33 41
5
P/J 5100
CURRENT SHUNT CABINET
B
9
SIGNALS 10
NEGATIVE (-) TERMINAL 11
A
POSITIVE (+) TERMINAL
CELL VOLTAGES
CELL VOLTAGES
COUPLE CABLE (BD SIDE)
SIGNALS 10
HEATER POWER 8
MAIN HEATER POWER
ALLIS-CHALMERS — NASA ELECTRICAL INTER-FACE

01	3-1-66	RGM
	ELECTRICAL INTERFACE CHANGED TO INDICATE THAT THE ALLIS-CHALMERS AUX. RELAY BOX, CONTROL PANEL AND ASSOCIATED CABLES, ALL INDICATED THUS (O), ARE NOT TO BE SHIPPED.	
02		



TES- CONTINUED

MS INDICATED THUS (7) NOT TO BE SHIPPED NASA. SAME ARE TO BE ED ONLY FOR TEST AT ALLIS-ALMERS. NASA TO FURNISH UIVALENT EQUIPMENT FOR EIR TESTS.

NEGATIVE(-)

NOTES:

1. WRAP FUEL CELL INSULATION WITH ALUMINUM FOIL TAPE BEFORE PERFORMING ANY VACUUM CHAMBER TESTS.
2. PRIOR TO SHIPPING, H_2, O_2 & H_2O CAVITIES & CANISTER SYSTEM TO BE PRESSURIZED TO 5PSI WITH HELIUM GAS AFTER EVACUATION OR PURGING OTHER GASES FROM SYSTEM. (*)
3. AFTER CANISTER COOLANT SYSTEM HAS BEEN PRESSURIZED, CRIMP & SEAL 0.25" O.D. TUBING HELIUM FILL LINE LOCATED AT BOTTOM MOUNTING PLATE.
4. HEAVY CABLE LINES ARE A-C SUPPLIED ITEMS. LIGHT CABLE LINES ARE NASA OR TEST LAB SUPPLIED.
5. WAS CONNECTOR J1004, THERMOCOUPLE CABLE ON ORIGINAL SYSTEM NO. 5 DEFINITION. (FOR INFORMATION ONLY)
6. WAS CONNECTOR J1006, MAIN HEATER CABLE ON ORIGINAL SYSTEM NO. 5 DEFINITION. (FOR INFORMATION ONLY)
7. TUBING ADAPTERS SHOWN ARE THE MATING PARTS REQUIRED TO CONNECT TO THE FUEL CELL AND NRS.
8. FOR INTERFACE SCHEMATIC SEE DRG. 49-500-125-404

(*) CAUTION- PRESSURE SHOULD BE INCREASED OR DECREASED GRADUALLY TO INSURE MAX. PRESSURE DIFFER. BETWEEN H_2 AND O_2 PRESSURE GAUGE IS LESS THAN 2 PSI.

PARTS LIST 49-200-431-504

CONFIDENTIAL – PROPERTY OF ALLIS-CHALMERS MFG. CO. 3341-RESEARCH MT. WORKS

NAME: FUEL CELL SYSTEM 5R

MATL.

UNLESS OTHERWISE SPECIFIED: 1-PLACE DEC ± / 2-PLACE DEC ± / 3-PLACE DEC ± / ANGULAR ±

MACHINED SURFACE TEXTURE

FIGURE 2-2A

WT.

DR. GAM/GP 2-15-66 / CH. SPANAUS 3/1/66 / AP. Michel Yol...

SIMILAR TO

SCALE | SHEET

PART NO. 49-400-260-405

0-260-405 | 02

PRINTED IN U.S.A.

REQ.	ITEM	DESCRIPTION	PART NUMBER
1	1	Fuel Cell System #5R PIX	49-400-260-405
1	2	Fuel Cell Assembly	49-500-105-510
1	3	Interface Schematic	49-500-125-404
1	4	Electrical Monitoring and Control Subsystem (EMCS)	49-200-585-502
1	5	Current Shunt Cabinet	49-200-432-501
1	6	Auxiliary Relay Box — DO NOT SHIP - USE FOR TEST AT ALLIS-CHALMERS ONLY	49-200-550-501
1	7	Control Panel	49-200-549-501
1	8	Cable, Stand-by Heater Power	49-200-522-501
1	9	Cable, RCSS to EMCS Valves	49-300-513-501
1	10	Cable, EMCS to Thermistors, Shunt Cab, and Transducers	49-100-706-501
1	11	Cable, -28V D-C Stack	49-100-588-502
1	12	Cable, Aux. Relay Box to Control Panel — DO NOT SHIP - USE FOR TEST AT ALLIS-CHALMERS ONLY	49-300-520-501
1	13	Cable, EMCS to Aux. Relay Box	49-300-506-501
1	14	Cable, EMCS to Control Panel	49-200-523-501
1	15	Electrical Connector (P 5001)	MS3116E-18-3S(SR)
1	16	Electrical Connector (P5002)	MS3116E-18-3Sx (SR)
1	17	Electrical Connector (P5006)	MS3116E-14-19 SW (SR)
1	18	Electrical Connector (P1000) Bendix	PT06A-14-19S(SR)

7-9 R-1

1	19	Electrical Connector (P3001)	MS3116E-20-41S (SR)
2	20	Electrical Connector (P1002-P1003)	MS3116E-16-26S (SR)
1	21	Electrical Connector (P1005)	BL06-14-18S-TC2
1	22	Electrical Connector (P3003)	MS3106E-28-19S (SR)
2	23	Load Jumper Cable	49-100-588-501
2	24	Plug, Aluminum (Parker)	4-PNTX-D
1	25	Cap, Cres. (Parker)	8-FNTX-SS
2	26	Cap, Cres. (Parker)	6-FNTX-SS
2	27	Cap, Cres. (Parker)	4-FNTX-SS
3	28	Nut, Coupling Cres. (Parker)	PAH-124-C4W
2	29	Nut, Coupling Cres. (Parker)	PAH-124-C6W
3	30	Sleeve, Cres. (Parker)	PAH-125-C4
2	31	Sleeve, Cres. (Parker)	PAH-125-C6
3	32	Cap, Elec, Conn, Receptacle	MS3181-12N
7	33	Cap, Elec, Conn, Receptacle SHIP 4 ONLY (REMAINING 3 ON APPARATUS USED FOR TEST BUT NOT SHIPPED)	MS3181-14N
5	34	Cap, Elec, Conn, Receptacle	MS3181-16N
4	35	Cap, Elec, Conn, Receptacle SHIP 2 ONLY (REMAINING 2 ON APPARATUS USED FOR TEST BUT NOT SHIPPED)	MS3181-18N
1	36	Cap, Elec, Conn, Receptacle	MS3181-20N
4	37	Cap, Elec, Conn, Receptacle	MS3181-22N
1	38	Cap, Elec, Conn, Receptacle (Bendix)	10-70500-28
	39		
3	40	Cap, Elec, Conn, Plug	MS3180-12C
7	41	Cap, Elec, Conn, Plug SHIP 4 ONLY (REMAINING 3 ON APPARATUS USED FOR TEST BUT NOT SHIPPED)	MS3180-14C

2-2B2

5	42	Cap. Elec. Conn. Plug	MS3180-16C
4	43	Cap. Elec. Conn. Plug	MS3180-18C
1	44	Cap. Elec. Conn. Plug	MS3180-20C
4	45	Cap. Elec. Conn. Plug SHIP 1 ONLY (REMAINING 3 ON APPARATUS USED FOR TEST BUT NOT SHIPPED)	MS3180-22C
1	46	Cap. Elec. Conn. Plug (Bendix)	10-70506-28
	47		
1	48	Shipping Container	49-~~400~~-230-501
REF	49	End Item Configuration Control	49-300-488-401

01 3-10-66 R(J)
[illegible] 3-14-66 REL. E.O. 0134 [illegible]
IT. [illegible] ADDED [illegible] (7) TO IT. 32 [illegible]
02 4-2-66
[illegible] 4-5-66 REL. to. 01[illegible]
IT#22 WAS MS 3116
IT#49 WAS 300-388-401
03 4-15-66
[illegible] 4-15-66 REL. 600186
NOTE - DO NOT SHIP OR SHIP ONLY PORTION OF QUANTITY REQ. ADDED TO ITEMS 6, 7, 12 TO 17 INCL. 33, 35, 41 AND 45.

04 -

UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES & MACHINING TOLERANCES ARE: ANGLES ±

DIMENSIONS	UP TO 6 INCL.	OVER 6 TO 24 INCL.	OVER 24
FRACTIONAL	±	±	±
DECIMAL	±	±	±

— Confidential — Property of
ALLIS-CHALMERS MFG. CO., Milwaukee, Wis.

RESEARCH - 8841 DEPT.

DR'N RAR 3/9/66 CH'D SPANAUS 3/10/66
TR'D APP'D R G Michel 3/15/66

FUEL CELL SYSTEM
No. 5R (Parts List)

(NEXT ASSY. = NONE)
FIGURE 2-2B

SIMILAR TO SCALE

SHEET OF 49-200-431-504

1 2 3 4

A-C MFG. CO. MILWAUKEE, WIS. FORM 5081-6 5-55

RECOMMENDED SYSTEM #5R CONTROLS AND MONITOR LIGHTS

Support		Light Monitor
1.	Helium purge - valve control (switch)	x (open)
2.	115 Vac power (switch)	x (on)
3.	28 Vac auxiliary power (switch)	x (on)
4.	Fan power (switch)	x (on)
5.	WRS heater tape (switch)	x (on)
6.	Vacuum pump - 1.5 psia (switch)	x (on)
7.	Vacuum pump - reference vacuum (switch)	x (on)
8.	Coolant pump (switch)	x (on)
9.	Stack heater power (switch) 1600 watt should have circuit for thermostat	x (on)

Figure 2-3

REQ.	ITEM	DESCRIPTION	MATERIAL	PART NUMBER
X	1	AUXILIARY RELAY BOX ASSEMBLY (PIX)		49-400-318-401
1	2	BOX	6061-T4 ALUM	49-300-555-001
1	3	COVER	6061-T4 ALUM	49-300-556-001
1	4	CHANNEL	6061-T4 ALUM	49-300-557-001
2	5	MOUNTING PLATE	6061-T4 ALUM	49-100-768-001
1	6	NAMEPLATE	.06 LAMICOID	49-100-770-001
1	7	INSULATOR BOARD	.031 GLASS EPOXY G10	49-100-771-001
1	8	CIRCUIT BOARD	.062 GLASS EPOXY G10	49-200-608-001
2	9	BUS BAR	BRASS	49-200-606-001
X	10	SCHEMATIC WIRING DIAGRAM		49-400-314-401
1	11	CONNECTOR		MS3114E22-55PY
1	12	"		MS3114E22-55PX
11	13	RELAY, DPDT, 24 VDC, POTTER & BRUMFIELD SC11DB		49-200-550-013
30	14	TERMINAL, SOLDER, CAMBION TYPE 2051-1		49-200-550-014
22	15	" " , VECTOR T-13		49-200-550-015
4	16	UNIRING, INSULATED, BURNDY YEC-180		MS25311-180
4	17	" " BURNDY YEC-110		MS25311-110
11	18	SILICON RECTIFIER, MOTOROLA IN4003		49-200-550-018
8	19	MACHINE SCREW #4-40 x .37 FLT-HD CR-REC	CRES	MS24693-C4

2-4-A-1

6	20	NUT, HEX #4-40	"	NAS671C-4
100	21	LOCKWASHER, SPLIT, #4	"	MS35338-78
22	22	MACHINE SCREW, PAN HD, CROSS-REC, #4-40 x .37	"	MS51957-15
44	23	MACHINE SCREW, FIL-HD, #4-40 x .31	"	AN500D4-5
68	24	CLINCH NUT, #4-40, PENN ENGRG. SL4-40-2.		49-200-550-024
50 FT.	25	WIRE, BLACK, UNSHIELDED, B-20 (19/32) ALPHA 1856/19, COLOR 2		49-200-550-025
3 FT.	26	" , GRAY, " " " " " " 9		49-200-550-026
3 FT.	27	" , BROWN, " " " " " " 7		49-200-550-027
3 FT.	28	" , GREEN, " " " " " " 4		49-200-550-028
1 FT.	29	" , WHITE & RED, " " " " " " 12		49-200-550-029
1 FT.	30	" " & BLUE, " " " " " " 15		49-200-550-030
1 FT.	31	" " & YELLOW " " " " " " 14		49-200-550-031
4	32	TUBULAR BRAID, .078 I.D., ALPHA# 2163, 10 IN. LG.		QQ-B-575
4	33	" " .172 I.D., " # 2168, 10 IN. LG.		QQ-B-575
4 FT.	34	TUBING, HEAT REACTIVE, (MSFC-276)	276-11BKOD12DIA	49-200-550-034
4 FT.	35	" " "	276-11BKOD25 DIA	49-200-550-035
YES	36	SOLDER, SN-60	QQ-S-571 TYPE RA	49-200-550-036
YES	37	FLUX	MIL-F-14256 TYPE A	49-200-550-037
4 FT.	38	LACING, .030 FLAT NYLON, BLACK, ALPHA LC-136	MIL-T-713A	49-200-550-038

USED ON P/L: 49-200-431-504, -505
49-200-495-501, -502, -503

01 4-21-66 RGM
REV. 4/21/66 REL. ECO
ITEM (17) WAS 3 REQ.
ITEM (32) WAS 3 REQ.
ITEM (34) WAS 3 FT. REQ.
02 5-4-66 RGM

UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES & MACHINING TOLERANCES ARE:		ANGLES ±	
DIMENSIONS	UP TO 6 INCL.	OVER 6 TO 24 INCL.	OVER 24
FRACTIONAL	±	±	±
DECIMAL	±	±	±

— Confidential — Property of —
ALLIS-CHALMERS MFG. CO., Milwaukee, Wis.
RESEARCH 3341 DEPT.

DR'N DSH 4-15-66
CH'D 4-20-66
TR'D
APP'D RGM 4-16-66

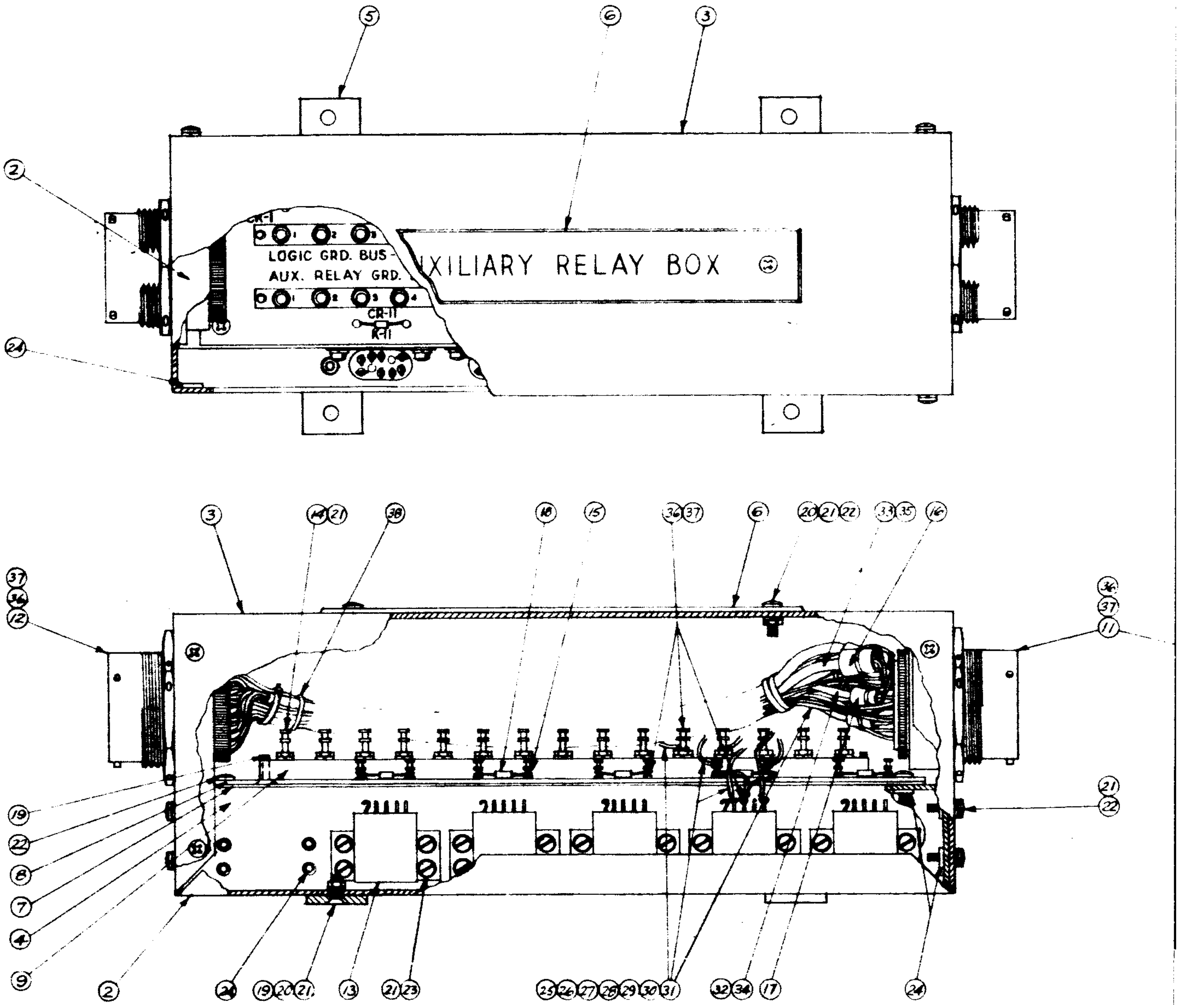
AUXILIARY RELAY BOX ASSEMBLY P/L

FIGURE 2-4A

SIMILAR TO: —
SCALE — =1
SHEET 1 OF 1

49-200-550-501

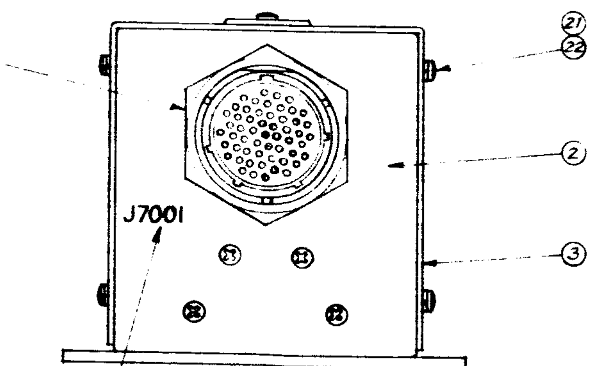
1 2 3 4


CR-1
LOGIC GRD. BUS
AUX. RELAY GRD.
CR-11
K-11
UXILIARY RELAY BOX

01 4-21-66

NOTES:

1. FOR SCHEMATIC WIRING DIAGRAM, SEE DRAWING 49-400-314-401.
2. SOLDER WHERE REQUIRED PER NPC-200-4.
3. HEAT SHRINK TUBING PER MSFC-PROC-273.
4. ROUTING, LACING, ETC. PER ELECTRICAL FABRICATION PROCEDURE MSFC-PROC-256.
5. CHECK FOR CONTINUITY PER SCHEMATIC.



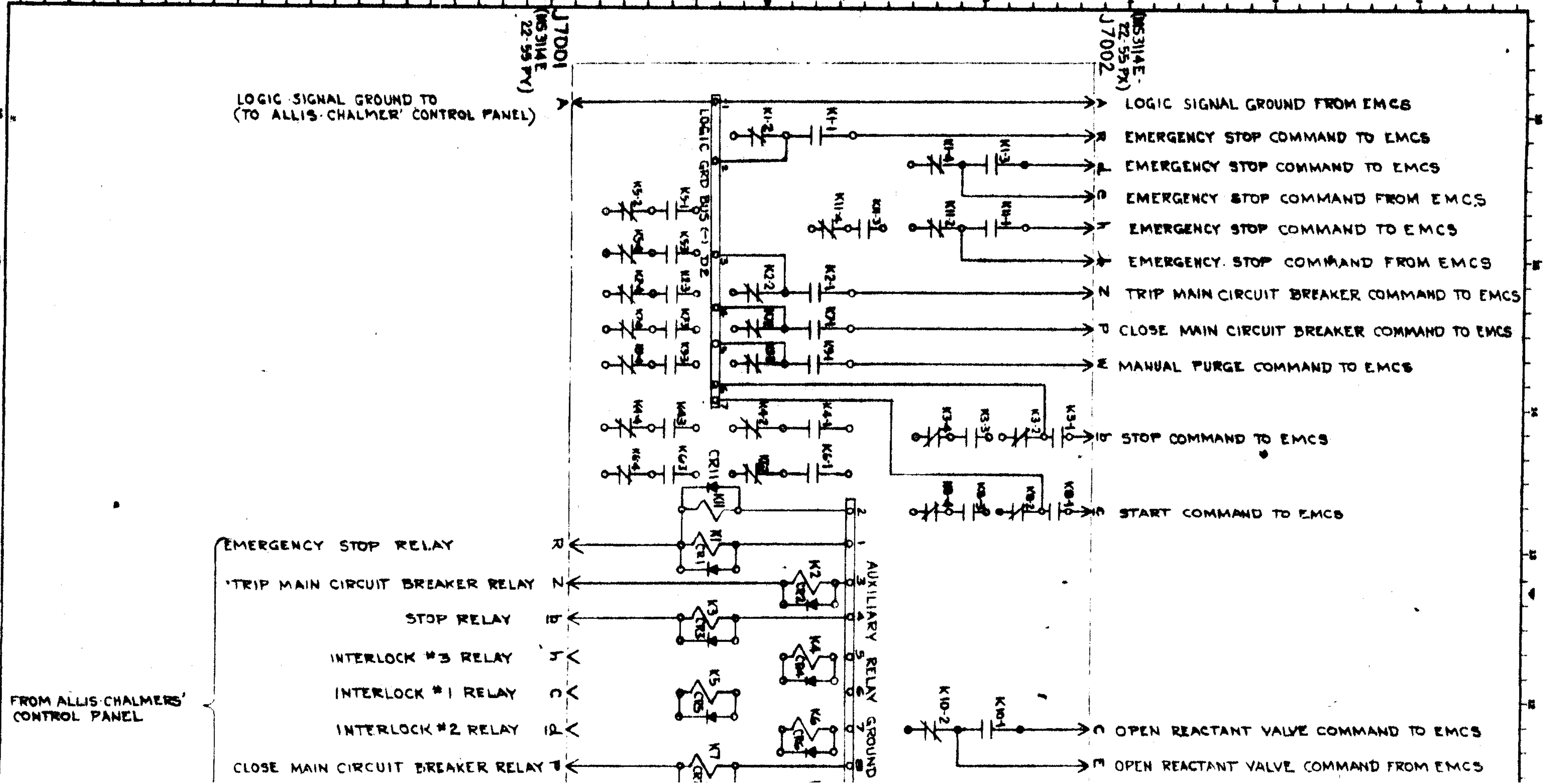
RUBBER STAMP CONNECTOR IDENTIFICATION NUMBERS IN WHITE, .19 HIGH. "J7001" ON SAME END AS ITEM (11). "J7002" ON OPPOSITE END.

USED ON P/L 49-200-550-501

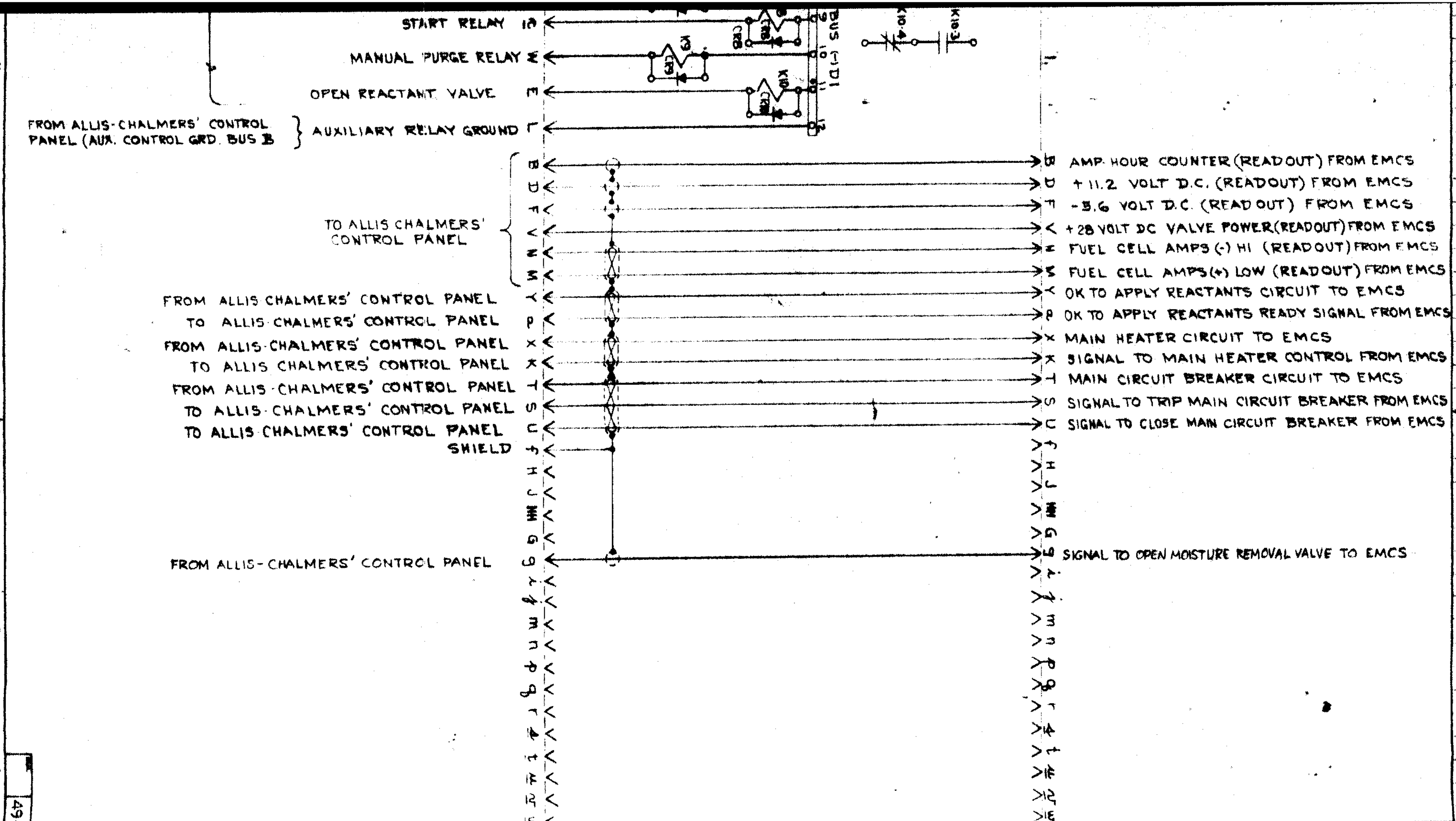
PROPERTY OF ALLIS-CHALMERS MFG. CO. RESEARCH 3341 PLANT	NAME: AUXILIARY RELAY BOX ASSEMBLY
UNLESS OTHERWISE SPECIFIED: 1-PLACE DEC ± 2-PLACE DEC ± 3-PLACE DEC ± ANGULAR ± / ✓ MACHINED SURFACE TEXTURE	MAT'L: —
	FIGURE 2-4B / WT.
DR. DSH 4-8-66 / CHKD. 4-20-66 / AP. RGID 4-26-66 / SIMILAR TO — / SCALE FULL / SHEET 1 of 1	PART NO. 49-400-318-401

49-400-318-401 | 01

PRINTED IN U.S.A.

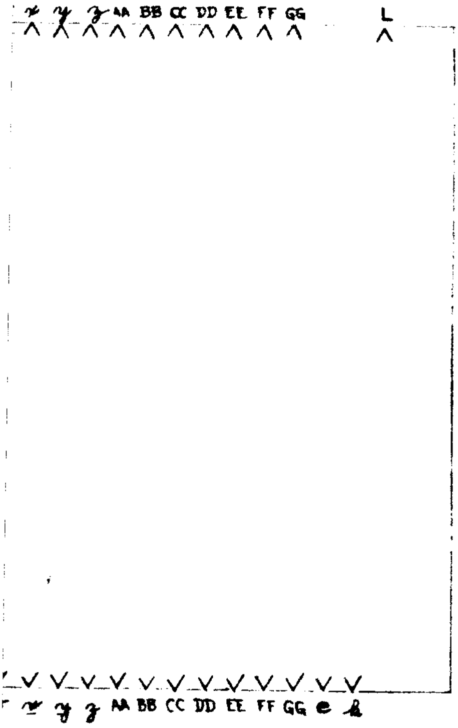

J7002
(MS3114E-22-55PX)
J7001
(MS3114E 22-55PY)
LOGIC SIGNAL GROUND TO
(TO ALLIS-CHALMER' CONTROL PANEL)
LOGIC SIGNAL GROUND FROM EMCS
EMERGENCY STOP COMMAND TO EMCS
EMERGENCY STOP COMMAND TO EMCS
EMERGENCY STOP COMMAND FROM EMCS
EMERGENCY STOP COMMAND TO EMCS
EMERGENCY STOP COMMAND FROM EMCS
TRIP MAIN CIRCUIT BREAKER COMMAND TO EMCS
CLOSE MAIN CIRCUIT BREAKER COMMAND TO EMCS
MANUAL PURGE COMMAND TO EMCS
STOP COMMAND TO EMCS
START COMMAND TO EMCS
OPEN REACTANT VALVE COMMAND TO EMCS
OPEN REACTANT VALVE COMMAND FROM EMCS
LOGIC GRD BUS (-) D2
AUXILIARY RELAY GROUND
EMERGENCY STOP RELAY
TRIP MAIN CIRCUIT BREAKER RELAY
STOP RELAY
INTERLOCK #3 RELAY
INTERLOCK #1 RELAY
INTERLOCK #2 RELAY
CLOSE MAIN CIRCUIT BREAKER RELAY
FROM ALLIS-CHALMERS' CONTROL PANEL

2-4C-1


START RELAY
MANUAL PURGE RELAY
OPEN REACTANT VALVE
AUXILIARY RELAY GROUND
FROM ALLIS-CHALMERS' CONTROL PANEL (AUX. CONTROL GRD. BUS B
BUS (-)D1
K9
CR9
K10
CR10
CR8
K10-3
K10-4
TO ALLIS CHALMERS' CONTROL PANEL
FROM ALLIS CHALMERS' CONTROL PANEL
TO ALLIS CHALMERS' CONTROL PANEL
FROM ALLIS CHALMERS' CONTROL PANEL
TO ALLIS CHALMERS' CONTROL PANEL
FROM ALLIS CHALMERS' CONTROL PANEL
TO ALLIS CHALMERS' CONTROL PANEL
TO ALLIS CHALMERS' CONTROL PANEL
SHIELD
FROM ALLIS-CHALMERS' CONTROL PANEL
AMP-HOUR COUNTER (READOUT) FROM EMCS
+11.2 VOLT D.C. (READOUT) FROM EMCS
-3.6 VOLT D.C. (READOUT) FROM EMCS
+28 VOLT DC VALVE POWER (READOUT) FROM EMCS
FUEL CELL AMPS (-) HI (READOUT) FROM EMCS
FUEL CELL AMPS (+) LOW (READOUT) FROM EMCS
OK TO APPLY REACTANTS CIRCUIT TO EMCS
OK TO APPLY REACTANTS READY SIGNAL FROM EMCS
MAIN HEATER CIRCUIT TO EMCS
SIGNAL TO MAIN HEATER CONTROL FROM EMCS
MAIN CIRCUIT BREAKER CIRCUIT TO EMCS
SIGNAL TO TRIP MAIN CIRCUIT BREAKER FROM EMCS
SIGNAL TO CLOSE MAIN CIRCUIT BREAKER FROM EMCS
SIGNAL TO OPEN MOISTURE REMOVAL VALVE TO EMCS
49

2-4C-2

01	4-8-66 B.R.B.
02	5-4-66



USED ON 49-200-550-501

CONFIDENTIAL – PROPERTY OF ALLIS-CHALMERS MFG. CO. 3341 MI WORKS	NAME SCHEMATIC DIAGRAM AUXILIARY RELAY BOX
UNLESS OTHERWISE SPECIFIED: 1-PLACE DEC ± 2-PLACE DEC ± 3-PLACE DEC ± ANGULAR ± — MACHINED SURFACE TEXTURE	MATL
	FIGURE 2-4C — WT
DR GJT 4-8-66 CH 4-8-66 AP — SIMILAR TO NONE — SCALE — SHEET	PART NO 49-400-314-401

100-314-401 02

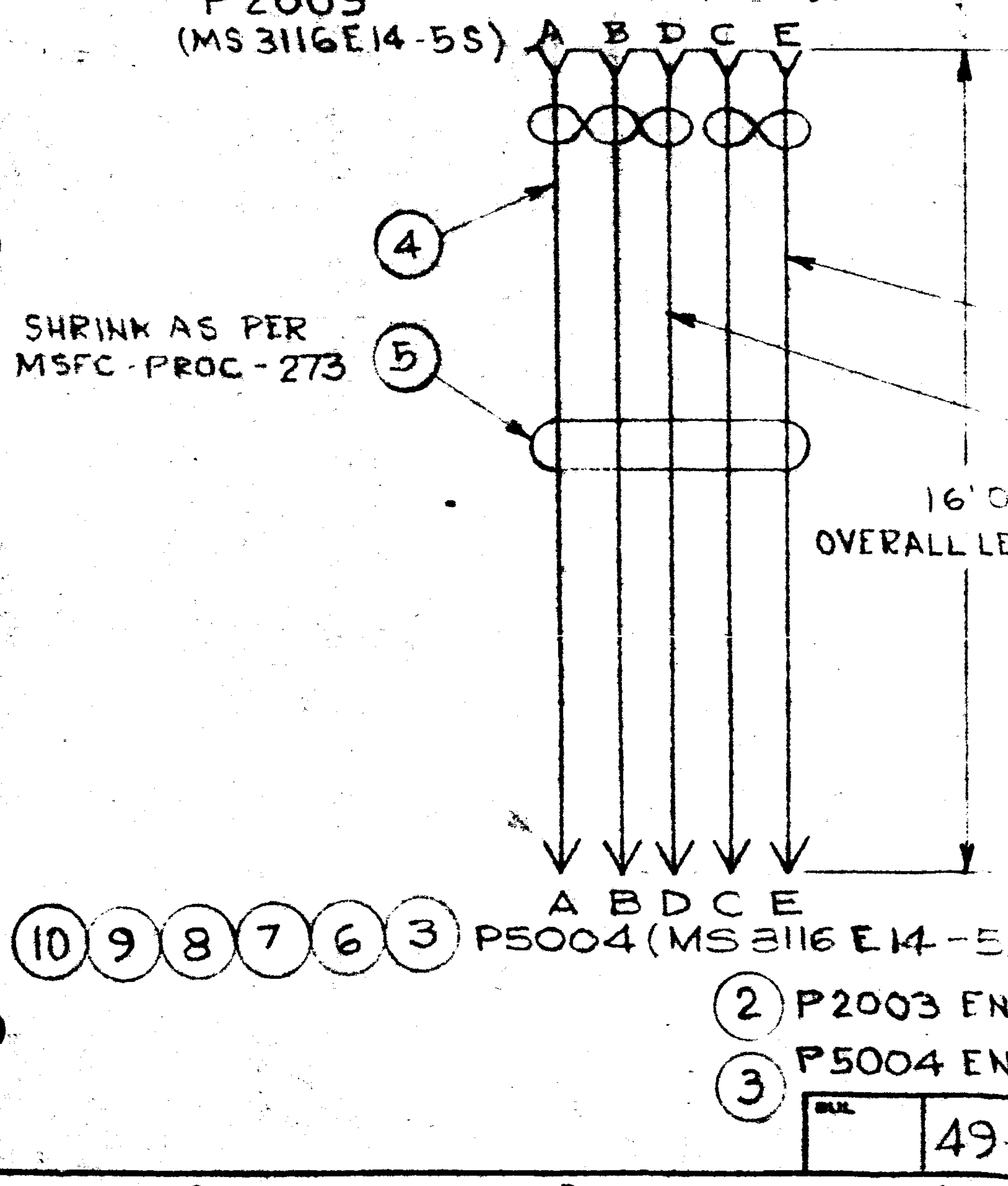
NOTE 1
EACH WIRE MUST BE CHECKED FOR ELECTRICAL CONTINUITY PER WIRING DIAGRAM.

NOTE 2
EACH WIRE MUST BE CHECKED FOR INSULATION RESISTANCE TO EACH OTHER WIRE, THE INSULATION RESISTANCE SHALL EXCEED 50 MEGOHMS AT 500 VOLTS D.C.

NOTE 3
SOLDER AS PER NPC 200-4

REQ	IT.	D
	1	CABLE, E
1	2	PLUG -
1	3	PLUG -
5	4	UNSHIELDE
1	5	.38 TUBING
2	6	BOOT STR
YES	7	ADHESIVE
YES	8	SOLDER
YES	9	SOLDER
2	10	.38 TUBING

10 9 8 7 6 2
P2003
(MS 3116E14-5S)



49-

2·5-1

ESCRIPTION	MATEF
MCS TO CONTROL PANEL	
D WIRE B16(19/29) 600V - 18 FT LG.	49-150-00
, HEAT REACTIVE (MSFC-276) 18 FT LG.	276-31BK0
AIGHT THIN WALL 202 A0 42-3	
- RAYCLAD S-1006	
SN 60	QQ - S - 5 TYPE RA
FLUX	MIL-F-142 TYPE A
, HEAT REACTIVE (MSFC-276) 1.0 IN. LG	276-31BK0

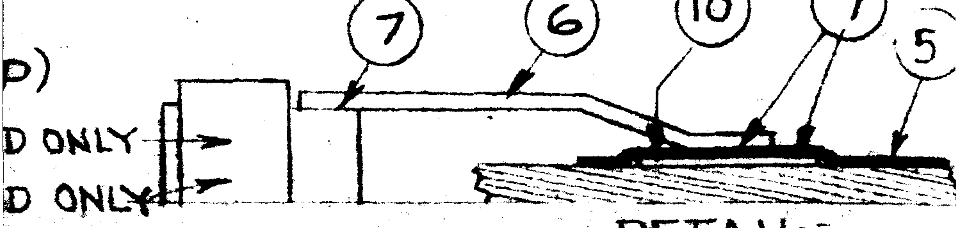
NOTE 4.
RUBBER STAMP OR STENCIL C
NUMBERS (P2003 AND P500
CONNECTORS USING CHARAC
SIMILARLY APPLY "PART N
MIDWAY BETWEEN CONNECT

HELICALLY TWIST TWO LENGTHS OF ITEM
TO FORM A MULTI-CONDUCTOR CABLE

HELICALLY TWIST THREE LENGTHS OF I
$\frac{+6"}{-0}$ TO FORM A MULTI-CONDUCTOR CABLE
NGTH

FINALLY HELICALLY TWIST THE AB
ONE CABLE. LENGTH OF LAY 3.5 TO
LAY TO BE OPPOSITE THAT OF INDIVI

NOTE 5
FOR ASSEMBLY PROCEDURE SEE
RAYCLAD THERMOFIT INSTRUCTION
BOOK.



200-523-501 | ISSUE 02

DETAIL
CABLE ENDS

2-5-9

IAL	PART NO.
	49-200-523-501
	MS 3116 E14-5S
	MS 3116 E14-5P
9-013	49-200-523-004
D38DIA	49-200-523-005
	49-250-014-004
	49-150-010-003
1	49-200-523-008
56	49-200-523-009
038DIA	49-200-523-010

01	3-23-66 D.R.B.	RGM
CHNG 3-23-66	REL. EO 144	
ITEM 5 WAS .50 TUBING 276-31BK OD 50 DIA. IT 10 ADDED (A-4) DETAIL ADDED		
02	4-30-66 D.P.B.	RGM
[illegible]	REL. EO [illegible]	

ONNECTOR IDENTIFICATION
4) ADJACENT RESPECTIVE
TERS APPROXIMATELY .12 HIGH.
O. 49-200-523-501
ORS.

4 }
T.4 } FORM ONE TURN FOR EACH 1.6 TO 2.2 INCHES OF LENGTH, DIRECTION OF LAY TO BE THE SAME FOR BOTH CABLES.

OVE TWO CABLES TO FORM
49 INCHES. DIRECTION OF
DUAL CABLES.

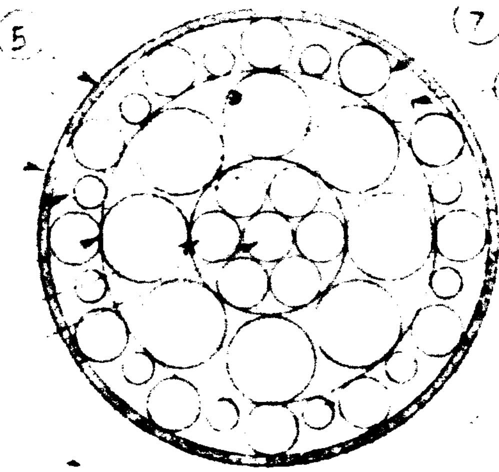
USED ON ASSY
49-200-495-501

CONFIDENTIAL—PROPERTY OF ALLIS-CHALMERS MFG. CO. M I PLANT	NAME: CABLE, EMCS TO CONTROL PANEL P2003 TO P5004
UNLESS OTHERWISE SPECIFIED: 1-PLACE DEC ± 2-PLACE DEC ± 3-PLACE DEC ± ANGULAR ± — MACHINED SURFACE TEXTURE	MATL
	FIGURE 2-5 — WT R F
DR GJT 3-23-66 / CHK D.P.B. 3-23-66 / AP RGM 3/24/66 — SIMILAR TO — SCALE NTS — SHEET —	PART NO. 49-200-523-501

3 2 PRINTED IN U.S.A. FORM NO. 8131-1

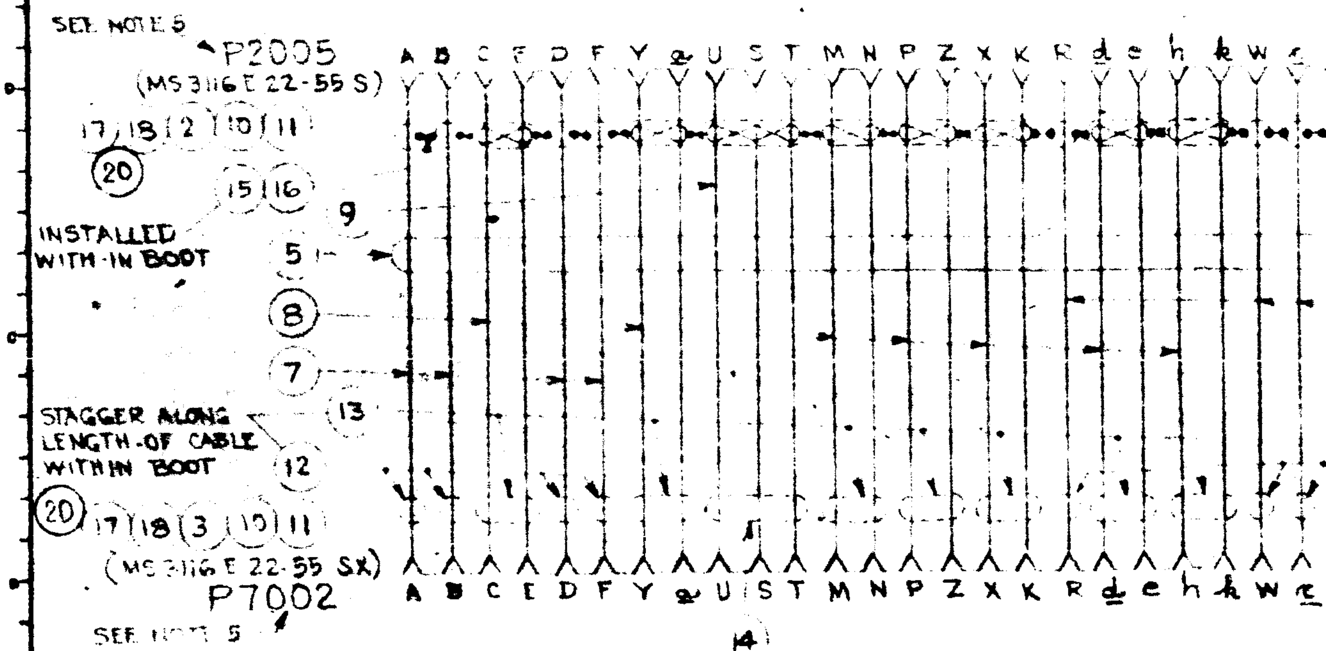
SHRINK AS PER
MSFC PROC 273 (5)

SECTION THRU
CABLE



REQ	IT	DESCRIPTION
	1	CABLE ... TO AUX ...
	2	PL...
	3	PL...
2	4	UNSH... WIRE B20
	5	... HEAT REACTIVE
12	6	SIZE ... SEAL
9	7	SHIELDED CABLE ONE B20
7	8	SHIELDED CABLE TWO B20
1	9	SHIELDED CABLE THREE B...
YES	10	ADHESIVE - RAYCLAD S...
2	11	BOOT STRAIGHT THIN WALL
19	12	INSULATED UNIFORM
7	13	INSULATED UNIFORM
1	14	INSULATED UNIFORM
1	15	...
1	16	UNINSULATED ...
YES	17	SOLDER SN 60
YES	18	SOLDER FLUX
1	19	UNSHIELDED WIRE B20
2	20	15 TUBING, HEAT REACT...

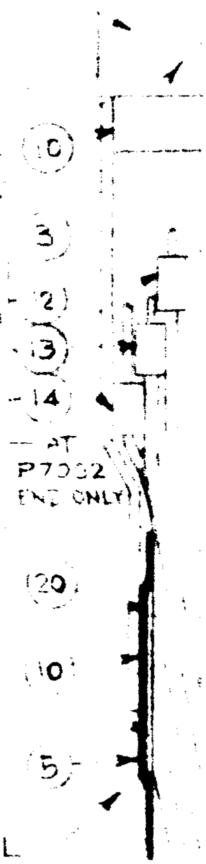
CORE TO CONSIST OF ONE LENGTH OF SINGLE CONDUCTOR
SHIELDED (ITEM 7)
FIRST LAYER TO CONSIST OF -
SIX LENGTHS OF SINGLE CONDUCTOR SHIELDED (ITEM 7)
HELICALLY TWIST ABOUT CORE TO FORM ONE TURN FOR
EACH 3.2 TO 4.5 INCHES OF LENGTH
SECOND LAYER TO CONSIST OF
SEVEN LENGTHS OF TWO CONDUCTOR SHIELDED (ITEM 8)
ONE LENGTH OF THREE CONDUCTOR SHIELDED (ITEM 9)
DIRECTION OF LAY OPPOSITE THAT OF FIRST LAYER
LENGTH OF LAY 7.0 TO 9.8 INCHES OF LENGTH
THIRD LAYER TO CONSIST OF -
12 LENGTHS OF SINGLE CONDUCTOR SHIELDED (ITEM 7)
12 LENGTHS OF SINGLE CONDUCTOR UNSHIELDED (ITEM 4)
DIRECTION OF LAY-OPPOSITE THAT OF SECOND LAYER
LENGTH OF LAY - 9.1 TO 12.7 INCHES OF LENGTH



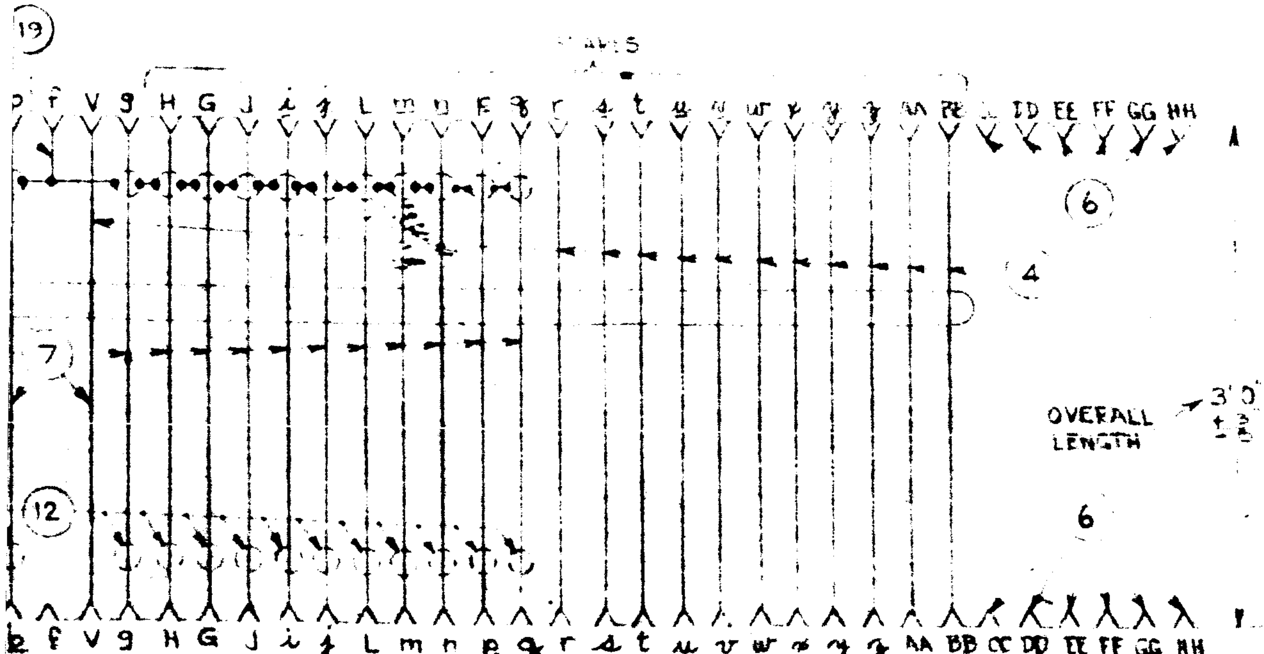
NOTE 1. EACH WIRE MUST BE CHECKED FOR ELECTRICAL CONTINUITY PER W...
2 EACH WIRE MUST BE CHECKED FOR INSULATION RESISTANCE TO EAC...
THE INSULATION RESISTANCE SHALL EXCEED 50 MEGOHMS AT ...
3 SOLDER AS PER NPC 200-4
4 FOR ASSEMBLY PROCEDURE SEE RAYCLAD THERMOFIT INST...
5 RUBBER STAMP OR STENCIL CONNECTOR IDENTIFICATION NUMBERS (...
RESPECTIVE CONNECTORS USING CHARACTERS APPROXIMATELY .1...
SIMILARLY APPLY "PART NO. 49-300-506-501 MIDWAY BETWEEN...
6 APPLY SHIELD TERMINATIONS (ITEMS 12 THRU 16 INCLUSIVE) AS...

		MATERIAL	PART NO
LAY BOX			49 300 506 501
			MS3116E22 55S
			MS3116E22 55SX
(19/32) 600V	48 IN LG	49 150 009 010	49 300 506 004
MSFC 276)	42 IN LG	276 BK 1200 DIA	49 300 506 00[illegible]
NG PLUG			49 150 011-001
(19/32)	48 IN LG	49 150 009 090	49 300 506 007
(19/32)	48 IN LG	49 150 009-106	49 300 506 008
D (19/32)	48 IN LG	49 150 009-[illegible]8	49 300 506 009
1006			49 150 010-003
202A074 3			49 250 014-007
			MS 25311-110
			MS 25311-150
			MS 25311-[illegible]
22			49 150 012-[illegible]8
NG YOC 872			49 150 012-021
		QQ-S-571 TYPE RA	49 300 506-017
		[illegible]-14256 TYPE A	49 300 506-018
9/32) 600V	[illegible] IN LG	49 150-009-026	49 300-506-019
E(MSFC-276)	15 IN LG	276 3 BK 1 50 DIA	49 300 506 020

ITEM 20 ADDED
(F-4) DETAIL ADDED



DETAIL
END OF CABLE



USED ON ASSY
49-200-495-501

IRING DIAGRAM.
OTHER WIRE.
500 VOLTS D.C.

RUCTION BOOK.
2005 AND P7002) ADJACENT
HIGH.
CONNECTORS.
PER ABMA-PD-E-53.

CONFIDENTIAL — PROPERTY OF
ALLIS-CHALMERS MFG. CO.
3341 MI WORKS

NAME: CABLE
EMCS TO AUX RELAY BOX
(P2005 TO P7002)

SCALE: NTS
SHEET: —

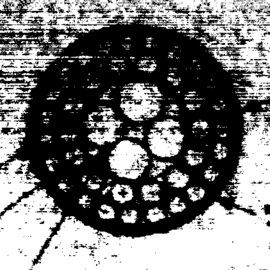
FIGURE 2-6

PART NO: 49-300-506-501

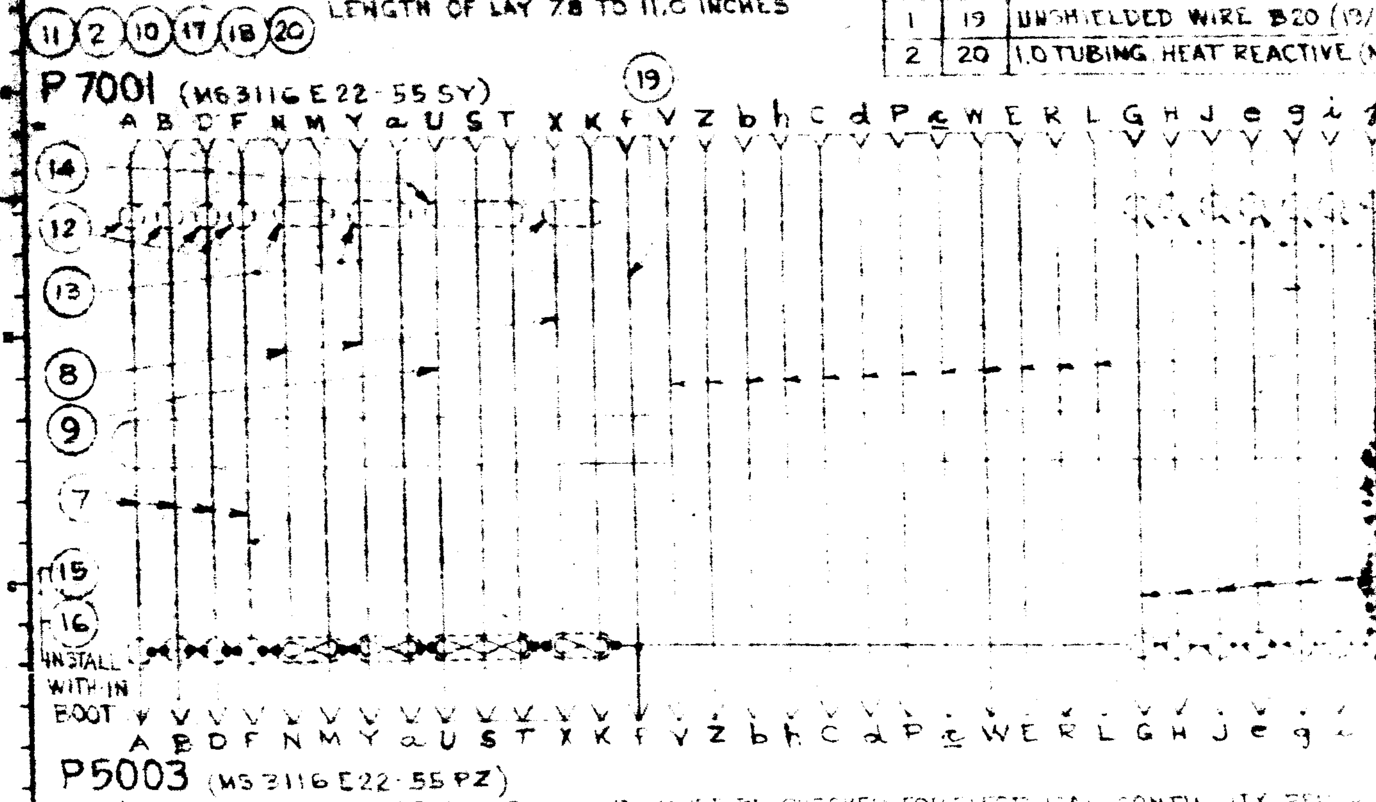
49-300-506-501
03

2-6-2

QTY	ITEM	DESCRIPTION
X	1	[illegible]
1	2	PLUG
1	3	PLUG
10	4	[illegible] SEAL
1	5	I.D. TUBING, HEAT REACTIVE (MS
22	6	UNSHIELDED WIRE B20 (19/
14	7	SHIELDED SINGLE WIRE B20 (19/
3	8	SHIELDED CABLE TWO B20 (19/
1	9	SHIELDED CABLE THREE B20 (
2	10	BOOT STRAIGHT THINWALL 2
YES	11	ADHESIVE RAYCLAD S
14	12	INSULATED UNIRING
3	13	INSULATED UNIRING
1	14	INSULATED UNIRING
1	15	INNER HYRING - YIC 880
1	16	UNINSULATED OUTER HYRI
YES	17	SOLDER SN60
YES	18	SOLDER FLUX
1	19	UNSHIELDED WIRE B20 (19/
2	20	I.D. TUBING HEAT REACTIVE (M



CORE TO CONSIST OF:
ONE LENGTH OF THREE CONDUCTOR SHIELDED CABLE (ITEM 9)
THREE LENGTHS OF TWO CONDUCTOR SHIELDED CABLE (ITEM 8)
HELICALLY TWIST TO FORM ONE TURN FOR EACH 4.4 TO 6.1 INCHES OF LENGTH.
CENTER LAYER TO CONSIST OF:
14 LENGTHS OF SINGLE CONDUCTOR SHIELDED (ITEM 7)
DIRECTION OF LAY OPPOSITE THAT OF CORE.
LENGTH OF LAY 6.5 TO 9.1 INCHES
OUTER LAYER TO CONSIST OF:
23 LENGTHS OF UNSHIELDED SINGLE CONDUCTOR WIRE (ITEMS 6 & 19)
DIRECTION OF LAY TO BE OPPOSITE THAT OF CENTER LAYER
LENGTH OF LAY 7.8 TO 11.0 INCHES

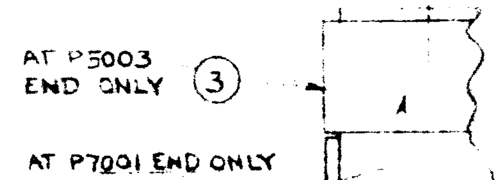


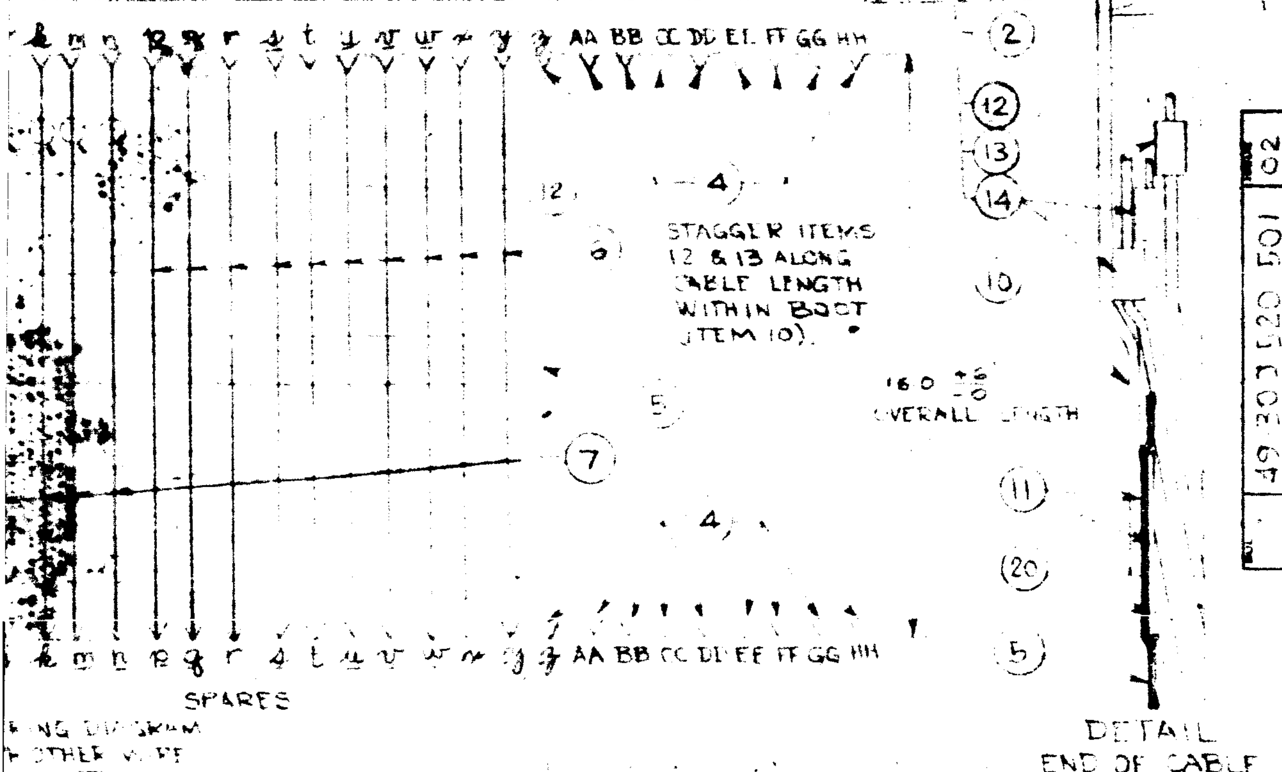
NOTE 1. EACH WIRE MUST BE CHECKED FOR ELECTRICAL CONTINUITY PER ...
2. EACH WIRE MUST BE CHECKED FOR INSULATION RESISTANCE TO ... THE INSULATION RESISTANCE SHALL EXCEED 50 MEGOHMS AT 5...
3. SOLDER AS PER MPC 200-4
4. FOR ASSEMBLY PROCEDURE SEE RAYCLAD THERMOFIT INSTR...

5. R [illegible]
[illegible]
[illegible]
[illegible] APPLY PART NO. 49 300-520-501
[illegible]
[illegible] APPLY SHIELD TERMINATIONS (ITEMS 12 THRU 16 INCLUSIVE...

2-7-1

	MATERIAL	PART NO.
... CONTROL PANEL		49-300-520-00[illegible]
[illegible]		MS 3106[illegible]
[illegible]		MS 3106[illegible]
...ING PLUG		49-150-011-001
...FC-276) 18 FT LG	276-31BK-1DOODIA	49-300-520-005
...32) COND. 18 FT LG	49-150-009-010	49-300-520-006
...32) COND. 18 FT LG	49-150-009-090	49-300-520-007
.../32) COND. 18 FT LG	49-150-009-106	49-300-520-008
.../32) COND 18 FT LG	49-150-009-138	49-300-520-009
...2 AQ74-3		49-250-014-007
...DOG		49-150-010-003
		MS 25311-110
		MS 25311-150
		MS 25311-160
		49-150-012-005
...G - YOC 676		49-150-012-019
	QQ-S-571 TYPE RA	49-300-520-017
	MIL-F-14256 TYPE A	49-300-520-018
...32) COND 19 FT LG	49-150-009-026	49-300-520-019
...SFC-276) 1.5 IN LG	276-31BK-1DOODIA	49-300-520-020





...ING DIAGRAM
...F OTHER WIRE
...O VOLTS D.C.

...TION BOOK

...) AS PER ABMA-PD-E-13.

CONFIDENTIAL PROPERTY OF
ALLIS-CHALMERS MFG. CO.
WORKS

UNLESS OTHERWISE SPECIFIED
1-PLACE DEC
2-PLACE DEC
3-PLACE DEC
ANGULAR

MACHINED SURFACE TEXTURE

NAME

MATL

FIGURE 2-7

WT

SIMILAR TO

DR
CH
AP

SCALE NTS

SHEET

PART NO 49-300-520-501

49-300-520-501 02

PRINTED IN U.S.A. FORM No.

provides additional information on the recommended test setup for the gases, liquid coolant, and the product water.

CAUTION: Care should be exercized in making all connections to prevent damage to electrical connectors and to insure leak tight tube connections. Refer to Paragraph 2.2 Initial Installation Checkout before making any external interface connections.

C. A data acquisition system and direct readout equipment, which must also provide the excitation voltage for the five (5) Allis-Chalmers' transducers to be monitored. A listing of the recommended functions and the method of monitoring or recording is contained in Figure 2-8.

D. Temperature recording equipment will be required for fuel cell temperatures. Allis-Chalmers will furnish mating connectors for the fuel cell module instrumentation, but not the cable. All thermocouple connections will be made up for iron constantan couples. No reference junction compensation circuits are furnished.

E. The 400-cycle three-phase power for the fuel cell coolant fans rated to supply at least 150 watts at 200 volts.

F. The customer will furnish the electrical load bank for the fuel cell output capability testing and the load disconnect contactor.

RECOMMENDED MONITOR FUNCTIONS FOR SYSTEM #5R

		Digitec	Panel Meter	VIV Recorder	Data Acquis.	Other
1.	Total fuel cell voltage (Both on Panel Control)		x	x	x	
2.	Total fuel cell current (Both on Panel Control)		x	x	x	
3.	Stack temperature (TC-8 and TC-9)			x	x	
4.	Cavity pressure	x		x	x	
5.	Individual cell volts	x			x	
**6.	Fan current		x		x	
7.	Heater current (28 vdc, 1600 watts)		x		x	
8.	H_2 inlet pressure	x			x	
9.	O_2 inlet pressure	x			x	
10.	Canister pressure	x			x	
11.	-5.0 vdc				x	
12.	+11.2 vdc				x	
**13.	System "ON" lapse time		x			
**14.	Load "ON" lapse time		x			
**15.	WRS heating tape temperature		x		x	
16.	Stack thermocouples - inside (7 additional)				x	
17.	Fan No. 1 RPM	x			x	
18.	Fan No. 2 RPM	x			x	
**19.	Fan Voltage				x	
20.	Stack liquid coolant differential pressure				x	
*21.	Stack liquid coolant outlet temperature				x	x
*22.	Liquid coolant inlet temperature					
**23.	Inlet liquid coolant flow					
**24.	Liquid coolant-inlet pressure				x	
**25.	Liquid coolant-outlet pressure				x	
**26.	Helium inlet pressure				x	
**27.	H_2 supply pressure		x		x	
**28.	O_2 supply pressure		x		x	
29.	Barometric pressure				x	

* Function has changes of short duration requiring continuous recording if detailed information is required.

** Sensors to be provided by N A S A.

Figure 2-8

2.1.5 Supplementary Installation Information

Figure 2-9 (Connector Interface function description) contains additional interface information to aid in the assembly of the test setup.

2.2 INITIAL INSTALLATION CHECKOUT

2.2.1 Electrical Testing

The external interface connections should be verified as per Figure 1-2A, 1-2B, and 1-2C (Drawing No. 49-500-125-404) and Figure 2-2A (Drawing No. 49-400-260-405), NASA's interface should be checked prior to the initial application of any power or reactants.

Instrumentation calibration data for use during checkout and operating can also be found in Figure 2-9.

2.2.2 Leak Test

Prior to the initial operation of the fuel cell, the reactant gas system, the water removal cavity, and the canister enclosure must be subjected to a leak test. The following is the procedure for performing this test, but it should not be performed initially without a representative from Allis-Chalmers present. Figure 2-10 is a suggested schematic only.

NASA INTERFACE CONNECTIONS

J5001-NASA Control Panel

A	+ 28 vdc input from fuel cell
B	- 28 vdc input from fuel cell and main ground

J5002-NASA Control Panel

A	+ 28 vdc input from auxiliary supply
B	- 28 vdc input from auxiliary supply and main ground.

J5006-NASA Control Panel

A	Logic signal ground output
D	+11.2 vdc logic control voltage output - for monitor only
F	-5.6 vdc logic control voltage output - for monitor only
V	+ 28 vdc valve power output - for monitor only
K	+ 28 vdc output to main heater control - for 1,600 watt heater
G	- 28 vdc ground output to main heater control - for 1,600 watt heater
S	+ 28 vdc output to trip main circuit breaker
U	+ 28 vdc output to close main circuit breaker
H	- 28 vdc ground output to main circuit breaker

Optional Monitor Signals

J5006-B Amp-hour readout - <u>NOTE:</u> This signal is displayed on panel (Amp-Hour Counter)

J3003 - 1,600 watt heater

E	+ 28 vdc 29 amp heater power for first 800-watt heater
G	- 28 vdc ground heater power for first 800-watt heater
C	800-watt heater thermostat N.O. for first
H	800-watt heater thermostat N.O. 800-watt heater
M	Shield for Pins C and H, isolated from stack
J	+ 28 vdc 29 amp heater power for second 800-watt heater
K	-28 vdc ground heater power for second 800-watt heater
A	800-watt heater thermostat N.O. for second
B	800-watt heater thermostat N.O. 800-watt heater
L	Shield for Pins A and B, isolated from stack

Figure 2-9
Sheet 1 of 5

NASA INTERFACE CONNECTIONS

J1000- Fuel Cell Fans and RPM

E	Fan reluctance pickup "AC" side, output signal 150 millivolts peak-to peak at approximately 1300 cps representing 20,000
F	RPM to be fed into AC to DC converter for instrumentation readout.
G	Shield for Pin E and F.
J	Fan reluctance pickup "BC" side, output signal 150 millivolts peak-to peak at approximately 1300 cps representing 20,000
H	RPM to be fed into AC to DC converter for instrumentation readout.
T	Shield for Pin J and H
A	Phase "A" Fan power input for A-C Side, 200 Vac,
B	Phase "B" 400 cps, 3-phase at approximately
C	Phase "C" 0.15 amp. per phase
D	Shield for Pins A, B, and C carried through to motor, isolated from case ground.
K	Phase "A" Fan power input for B-D side, 200 Vac.
L	Phase "B" 400 cps, 3-phase at approximately
M	Phase "C" 0.15 amp. per phase
N	Shield for Pins K, L, and M carried through to motor, isolated from case ground.

NASA INTERFACE CONNECTIONS

CELL VOLTAGES - SYSTEM # 5R

Connectors J1002 and J1003 On The Fuel Cell

Cell No.	Plus Pin	Minus Pin
1	J1003b	J1002b
2	J1002b	J1002a
3	J1002a	J1003a
4	J1003a	J1003Z
5	J1003Z	J1002Z
6	J1002Z	J1002Y
7	J1002Y	J1003Y
8	J1003Y	J1003X
9	J1003X	J1002X
10	J1002X	J1002W
11	J1002W	J1003W
12	J1003W	J1003V
13	J1003V	J1002V
14	J1002V	J1002U
15	J1002U	J1003U
16	J1002U	J1003T
17	J1003T	J1002T
18	J1002T	J1002S
19	J1002S	J1003S
20	J1003S	J1003R
21	J1003R	J1002R
22	J1002R	J1002P
23	J1002P	J1003P
24	J1003P	J1003N
25	J1003N	J1002N
26	J1002N	J1002M
27	J1002M	J1003M
28	J1003M	J1003L
29	J1003L	J1002L
30	J1002L	J1002K
31	J1002K	J1003K
32	J1003K	J1003J
33	J1003J	J1002J

Spare Pins

J1002 - A, B, C, D, E, F, G, H   Pin c left open for cable shield tie point
J1003 - A, B, C, D, E, F, G, H   Pin c left open for cable shield tie point

Figure 2-9 (cont.)
(sheet 3 of 5)

NASA INTERFACE CONNECTIONS

Transducer Calibration Data

Note: All Transducers - 5000 ± 100 ohms element-max current 10 ma

J3001 Fuel Cell Pressure Transducer

i	O_2 Inlet absolute pressure transducer (pin i transducer ground)
h	+ Excitation voltage
f	- Excitation Voltage and - signal output
g	+ Signal output, 0-50 psia ± 1% Sensitivity 0.02 volt/psia/volt excitation
a	H_2 Inlet absolute pressure transducer (pin a transducer ground)
Z	+ Excitation voltage
X	- Excitation voltage and - signal output
Y	+ Signal output, 0-50 psia ± 1%. Sensitivity 0.02 volt/psia/volt excitation
e	Canister pressure transducer (pin e transducer ground)
d	+ Excitation voltage
b	- Excitation voltage and - signal output
C	+ Signal output, 0-50 psia ± 1% Sensitivity 0.02 volt/psia/volt excitation
J	Liquid coolant differential pressure transducer (pin J transducer ground)
H	+ Excitation voltage
F	- Excitation voltage and - signal output
G	+ Signal output, -10 to + 10 psid ± 1.25% Sensitivity 0.05 volt/psid/volt excitation
W	Water cavity readout pressure transducer (pin W transducer ground)
V	+ Excitation voltage
T	- Excitation voltage and - signal output
U	+ Signal output 0-25 psia ± 1%. Sensitivity 0.04 volt/psia/volt excitation

LIQUID COOLANT VALVE SUPERVISORY CONTACTS

B	Monitor signal - coolant valve close
C	Input signal to coolant valve connections
D	Monitor signal - coolant valve open

Figure 2-9
Sheet 4 of 5

NASA INTERFACE CONNECTIONS

OXYGEN PURGE VALVE SUPERVISORY CONTACTS

j	Monitor Signal - O_2 Purge Valve Close
k	Input Signal to O_2 Purge Valve Connections
m	Monitor Signal - O_2 Purge Valve Open

HYDROGEN PURGE VALVE SUPERVISORY CONTACTS

n	Monitor Signal - H_2 Purge Valve Close
p	Input Signal to H_2 Purge Valve Connections
q	Monitor Signal - H_2 Purge Valve Open

REACTANT INLET VALVE SUPERVISORY CONTACTS

k	Monitor Signal - Reactant inlet valve close
L	Input signal to reactant inlet valve connection
m	Monitor Signal - Reactant inlet valve open

J1005 FUEL CELL THERMOCOUPLE - INSIDE OF STACK

Pin	Polarity	Thermocouple No.	Location
A	Plus	1	In H_2O Plate#45-Corner A (Cell #11)
B	Minus		
C	Plus	2	In H_2O Plate#5 - Corner C(Cell #4)
D	Minus		
E	Plus	3	In H_2O Plate #129-Corner D (Cell#33)
F	Minus		
G	Plus	4	Under Heat Exchanger
H	Minus		
J	Plus	5	Fan Outlet Return A-C Side
K	Minus		
L	Plus	6	Fan Outlet A-C Side
M	Minus		
N	Plus	7	Fan Outlet B-D Side
P	Minus		
R	Plus	8	In Transister holder between O_2 Plate #75 and H_2 Plate #72-Corner A (cell 19)
S	Minus		
T	Plus	9	In Transistor holder between O_2 Plate #67, and H_2 Plate#64-Corner D(cell 17)
U	Minus		

Note: Plus is iron - Yellow
Minus is constantan - Red

Figure 2 - 9
Sheet 5 of 5

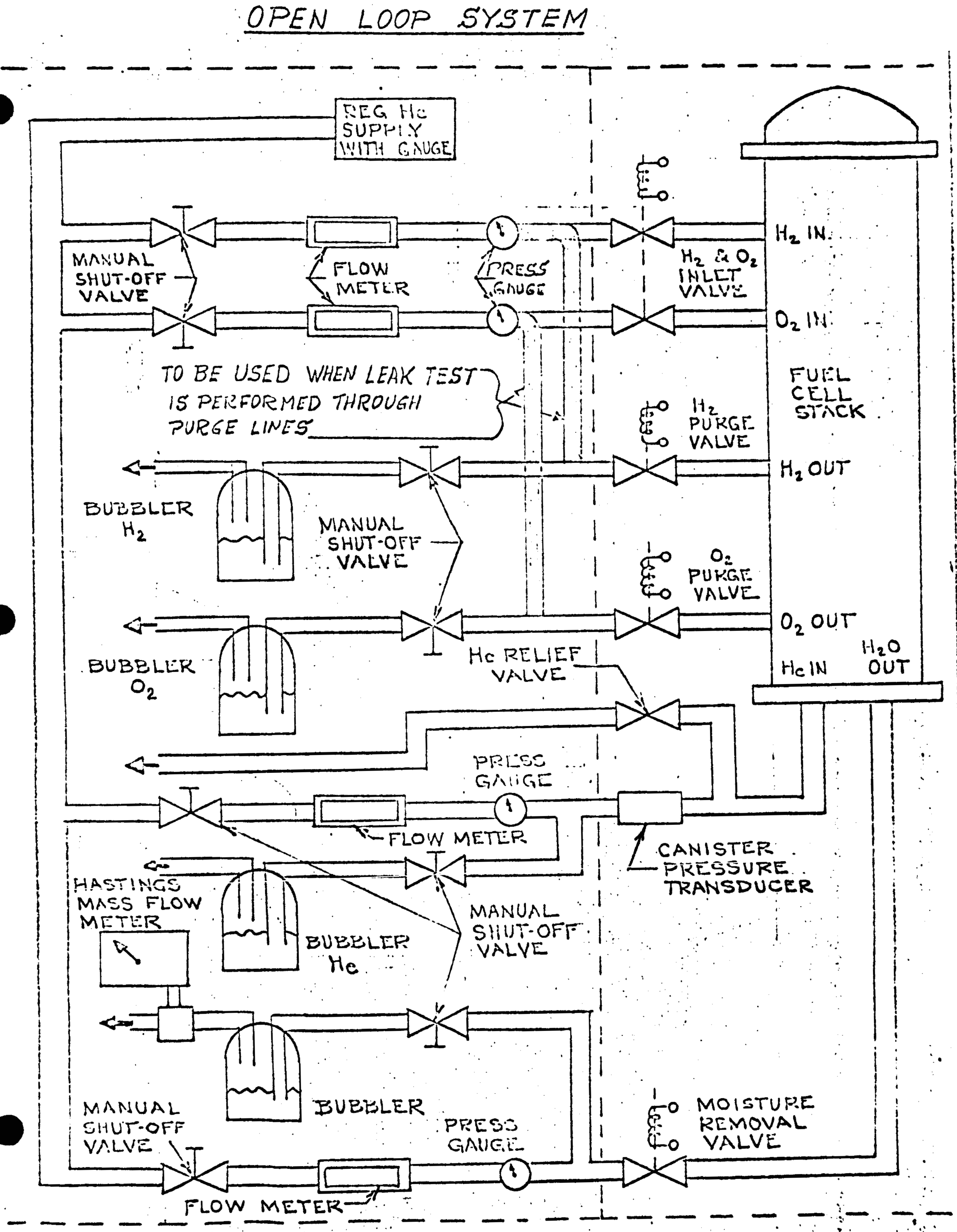

OPEN LOOP SYSTEM
REG He SUPPLY WITH GAUGE
MANUAL SHUT-OFF VALVE
FLOW METER
PRESS GAUGE
H2 & O2 INLET VALVE
H2 IN
O2 IN
TO BE USED WHEN LEAK TEST IS PERFORMED THROUGH PURGE LINES
FUEL CELL STACK
H2 PURGE VALVE
H2 OUT
BUBBLER H2
MANUAL SHUT-OFF VALVE
O2 PURGE VALVE
O2 OUT
BUBBLER O2
He RELIEF VALVE
He IN
H2O OUT
PRESS GAUGE
FLOW METER
CANISTER PRESSURE TRANSDUCER
HASTINGS MASS FLOW METER
BUBBLER He
MANUAL SHUT-OFF VALVE
BUBBLER
MANUAL SHUT-OFF VALVE
PRESS GAUGE
MOISTURE REMOVAL VALVE
FLOW METER

Figure 2-10

A regulated helium gas supply should be connected to each of the following lines on the fuel cell module.

(1) Hydrogen gas inlet or hydrogen purge line
(2) Oxygen gas inlet or oxygen purge line
(3) Helium gas inlet
(4) Moisture removal line (vapor vent)

The water vapor outlet from the fuel cell stack should be connected through a manual shut-off valve to a gas bubbler and a Hastings Mass Flowmeter for visual observation. The helium supply line to each of the above points should contain a manual shut-off valve and a pressure gauge downstream of the shut-off valve. A flow meter in each line is desirable but not mandatory. The hydrogen purge outlet and oxygen purge outlet should also discharge to the atmosphere through manual shut-off valves.

The detailed leak test procedure is as follows:

Cavity External Leak Check

(1) Bleed the helium pressure within the fuel cell canister to 0 psig from the helium fill line.

(2) Fill the reactant cavities with helium through the hydrogen and oxygen inlet lines or through the hydrogen and oxygen purge lines to 20 psig, and then depressurize to zero psig. Repeat.

CAUTION - The pressure should be increased or reduced gradually to insure that the maximum pressure difference between the hydrogen and oxygen pressure gauges is less than 2 psi.

(3) Close the purge valves (only when reactant cavities are filled through oxygen and hydrogen inlet valves), open the moisture removal cavity valve and the vapor vent.

(4) Apply helium pressure simultaneously to all three cavities until a pressure of 20 psig is reached, and allow to stand for ten (10) minutes. Observe the Caution note from Step 2.

(5) Shut off the supply valves and record the three cavity pressures after allowing to stand for 15 minutes. A pressure drop is indicative of a leak into the canister interior or valve leakage. The purge valve leakage may be checked by connecting the purge outlet lines to a gas bubbler. Leakage into the canister may also be checked by putting a bubbler on the canister helium fill line.

Cavity Cross Leak Check

(6) Open the helium supply valves and raise all cavity pressure back to an equalized pressure of approximately 20 psig and then close the hydrogen inlet or hydrogen purge valve and moisture removal valve.

(7) Continue to raise the pressure on the oxygen cavity, through the oxygen inlet line or oxygen purge line until a pressure of 22 psig is reached. Close the manual oxygen inlet valve or oxygen purge valve. Allow to stand for 15 minutes and record the reactant cavity pressures. A simultaneous drop in the oxygen cavity pressure and rise in the hydrogen cavity pressure is indicative of a cross leak.

(8) Open the moisture removal cavity valve and bleed the pressure gradually to zero (0) psig. Open the hydrogen and oxygen inlet valves and gradually pressurize both reactant gas cavities to thirty (30) psi differential across the water removal matrices. Leave the inlet or purge valves open. Allow to stand for 15 minutes and record the bubbles per minute observed in the vacuum vent line gas bubbler and record the Hastings Mass Flowmeter reading.

(9) Gradually bleed down all helium pressure to zero (0) psig.

Canister Leak Check

(10) Pressurize the fuel cell canister to 40 psi differential across the canister wall and open the purge lines and vacuum vent line from the vent graduate, to bubblers for visual observation. Disconnect the helium supply from the helium fill line thereby isolating the canister. Record canister pressure every half hour for twenty-four (24) hours along with room temperature. If at all possible, the room temperature should be held constant throughout the test.

(11) Any observable pressure drops during the tests detailed in Steps 1 through 10 should be reported immediately to the Allis- Chalmers designated representative or site representative. Any flow rate reading in excess of 25 cc/hour observed during the leak test outlined in Step 8 should be reported immediately to Allis-Chalmers. If the pressure drop during the fuel cell canister leak test as detailed in Step 10 exceeds one (1) psi in the twenty-four (24) hour test period, notify Allis- Chalmers.

2.2.3 Heating Tape

To prevent the product water vapor from condensing in the water removal line, the line must be heated from the moisture removal valve at the bottom of the fuel cell module to the water recovery condenser. A section of heating tape is provided for this purpose. The tape is applied by removing its backing and sticking it directly to the water removal manifold and tubing. Cut the tape to the desired length and attach the input leads as per Figure 1-2A (Drawing No. 49-500-125-404). The A-C power input to the input leads on breaking tone is provided from a Variac (See Figure 3-4).

Upon initial startup, adjust the temperature of the water removal line to $195 \pm 10^{o}F$ as follows:

a. Attach a thermocouple to the tubing to read tubing temperature.

b. Turn off 110 vac heater power "ON" after first assuring the Variac is set for minimum voltage.

c. Gradually, raise the heating tape voltage by turning the Variac clockwise until the desired steady-state tubing temperature is reached.

SECTION III

INTEGRATED SYSTEM OPERATION

3.1 GENERAL

This portion of the instruction manual covers the various operational modes of the complete fuel cell assembly, and includes the expected readings of all essential instrumentation. The description of the subsystems, and the thermocouple instrumentation are presented in Section IV of this manual.

3.2 PRE-STARTUP CONDITIONING OF THE SYSTEM (See A-C control panel Figure 3-1 (49-400-317-401), Figure 3-2 (49-200-549-501), Figure 3-3 (49-500-167-401) and NASA Control Panel Figure 3-4(49-400-349-402).

3.2.1 Initial Conditions

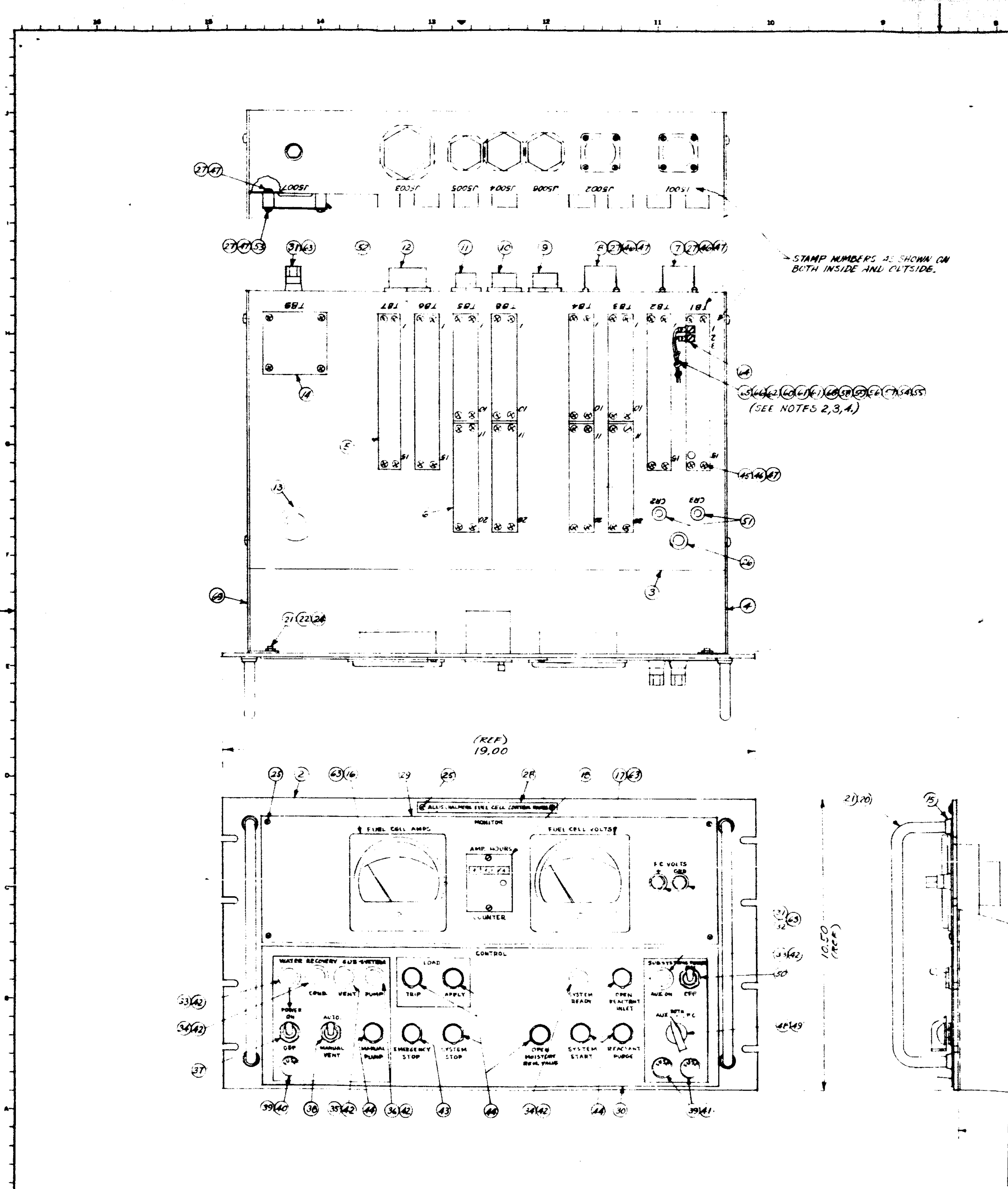
Pre-startup conditioning will be initiated with all valves closed, all switches off, and with system supplies as follows:

Hydrogen— per NASA specifications with minimum purity of 0.9998
—Regulator closed off,

Oxygen — per NASA specification with minimum purity of 0.99995
—Regulator closed off,

Helium — Commercial Grade
—Regulator closed off,

Vacuum— normal vacuum of at least 1.5 psia applied to the moisture removal line.

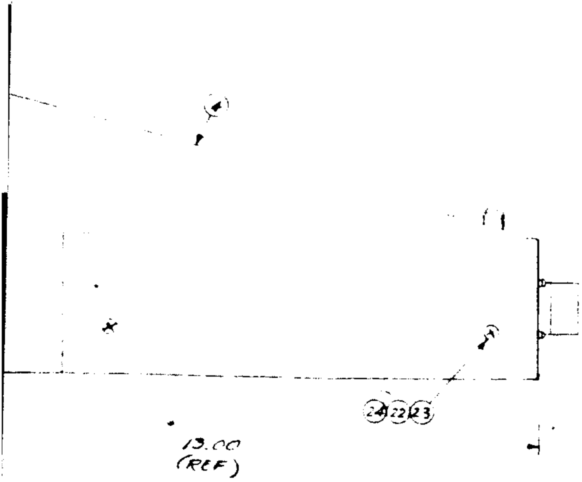


STAMP NUMBERS AS SHOWN ON BOTH INSIDE AND OUTSIDE.
(SEE NOTES 2,3,4.)
(REF) 19.00
10.50 (REF)
ALLIS-CHALMERS FUEL CELL CONTROL PANEL
MONITOR
FUEL CELL AMPS
AMP. HOURS
COUNTER
FUEL CELL VOLTS
F.C. VOLTS
CONTROL
WATER RECOVERY SUB-SYSTEM
LOAD
TRIP
APPLY
SYSTEM READY
OPEN REACTANT INLET
AUX ON
OFF
POWER ON
OFF
AUTO
MANUAL VENT
MANUAL PUMP
EMERGENCY STOP
SYSTEM STOP
OPEN MOISTURE REM. VALVE
SYSTEM START
REACTANT PURGE

01	4-16-66 D.P.D.	RLM
"OPEN MOISTURE DRAIN VALVE" AND (1) MORE ITEM (64) ADDED		
02	5-4-66	RLM

NOTES:

1. FOR WIRING SCHEMATIC, SEE DWG. 49-500-167-401.
2. SOLDER WHERE REQUIRED, PER NPC-200-4.
3. HEAT SHRINK TUBING PER MSFC-PROC-273.
4. ROUTING, CRIMPING, LACING, ETC PER ELECTRICAL FABRICATION PROCEDURE MSFC-PROC-256.
5. CHECK FOR CONTINUITY PER SCHEMATIC.



USED ON P/L 49-200-549-501

PROPERTY OF ALLIS-CHALMERS MFG. CO. RESEARCH 3341 WORKS	NAME ALLIS-CHALMERS CONTROL PANEL ASSEMBLY PIX	
UNLESS OTHERWISE SPECIFIED: 1-PLACE DEC ± 2-PLACE DEC ± 3-PLACE DEC ± ANGULAR ±	MACHINED SURFACE TEXTURE	MATL
DR 3-3-66 DSH	SIMILAR TO —	
CH D.P.D. 4-4-66	SCALE HALF SIZE	SHEET 1 OF 1
AP RLM 4-6-66	PART NO 49-400-317-401	

NO.	49-400-317-401	ISSUE 02

PRINTED IN U.S.A.

FIGURE 3-1-2

REQ.	ITEM	DESCRIPTION	PART NUMBER
X	1	CONTROL PANEL ASSEMBLY PIX	49-400-317-401
1	2	PANEL	49-300-530-001
1	3	CHASSIS BASE	49-400-347-001
1	4	RIGHT HAND BRACKET	49-300-531-001
4	5	TERMINAL STRIP, CINCH-JONES #15-140Y	49-200-549-005
8	6	" " " " #10-140Y	49-200-549-006
1	7	CONNECTOR, BENDIX	MS3102E18-3P
1	8	" "	MS3102E18-3PX
1	9	" "	MS3114E14-19SW
1	10	" "	MS3114E14-5S
1	11	" "	MS3114E12-10S
1	12	" "	MS3114E22-55SZ
1	13	GROMMET, .62 I.D, 1.25 O.D. RUBBER	49-200-549-013
1	14	AMPLIFIER CIRCUIT BOARD ASSEMBLY. (P/L)	49-200-611-501
4	15	FERRULES	49-200-549-015
1	16	AMMETER, 0-100 AMP DC, 100 MV, WESTON MODEL 301, SQUARE.	49-200-549-016
1	17	VOLTMETER, 0-50 V DC, 1000 Ω/VOLT, WESTON MODEL 301, SQUARE.	49-200-549-017
1	18	IMPULSE COUNTER, 24V, 25 IMP./SEC, SODECO TYPE TCEBZ6E.	49-200-549-018
X	19	SCHEMATIC WIRING DIAGRAM	49-500-167-401

2	20	HANDLE, PRECISION METAL PRODUCTS	49-200-549-020
10	21	MACHINE SCREW, #10-24 × .38, CROSS-REC, FLAT HD, CRES	MS24693-70
10	22	NUT, #10-24, HEX, CRES	MS35649-104
4	23	MACHINE SCREW, #10-24 × .38 CROSS-REC. PAN HD, CRES	MS51957-61
10	24	LOCKWASHER, #10, SPLIT TYPE, CRES	MS35338-81
6	25	MACHINE SCREW, #2-56 × .187, CROSS-REC, PAN HD, CRES	MS51957-2
1	26	GROMMET, .38 I.D., .62 O.D., RUBBER	49-200-549-026
16	27	MACHINE SCREW, #4-40 × .38, CROSS-REC. PAN HD, CRES	MS51957-15
1	28	NAMEPLATE	49-100-728-001
1	29	MONITOR SECTION PANEL	49-300-528-001
1	30	CONTROL " "	49-300-529-001
2	31	BINDING POST, BLACK, SUPERIOR DF30BC	49-200-549-031
1	32	" " , RED , " DF30RC	49-200-549-032
2	33	LENS, RED, SYLVANIA TYPE B0110	49-200-549-033
2	34	" , GREEN, " " B0112	49-200-549-034
1	35	" , AMBER, " " B0111	49-200-549-035
1	36	" , CLEAR, " " B0116	49-200-549-036
1	37	TOGGLE SWITCH, SPST, CUTLER-HAMMER 8803, CIRC. ON-NONE-OFF	49-200-549-037
1	38	" " , DPDT, " " 8825, CIRC. ON-NONE-ON	49-200-549-038
3	39	FUSEHOLDER, BUSS TYPE HKP	49-200-549-039
1	40	FUSE, STD. TYPE 3AG, 32V, 4 AMP, LITTELFUSE SERIES 311000	49-200-549-040
2	41	" " " " " , 15 AMP, " " "	49-200-549-041
6	42	HOUSING & LAMP COMBINATION, SYLVANIA UNIV. 28PB5/B0C99	49-200-549-042

1	43	PUSH BUTTON SWITCH, MOMENTARY SPST-NO, RED, ARROW-HART 3391GL	49-200-549-043
8	44	" " " " " BLACK " "	49-200-549-044
48	45	MACHINE SCREW, #4-40 x .50, CROSS-REC. PAN HD, CRES	MS51957-17
58	46	NUT, #4-40 HEX, CRES	NAS671C-4
64	47	LOCKWASHER, #4, SPLIT TYPE, CRES	MS35338-78
1	48	SWITCH, ROTARY, SHORTING, 2-SECT, 2 POLE/SECT, 9 AMP, CENTRALAB JV-9034	49-200-549-048
1	49	KNOB, POINTER TYPE, BLACK BAKELITE W/.25 HOLE, SET SCR, DAVIES 2300	49-200-549-049
1	50	TOGGLE SWITCH, DPST, CUTLER-HAMMER 8823, CIRC. ON-NONE-OFF	49-200-549-050
2	51	SILICON RECTIFIER, TEXAS INSTRUMENT TYPE IN1583	49-200-549-051
4	52	NYLON SPACER, .25 O.D. x .75 LG, #4-40 THD.	49-200-549-052
4	53	WASHER, FLAT, .125 I.D., .250 O.D., CRES	MS15795-803
4	54	UNIRING, INSULATED, BURNDY YEC-180	MS25311-180

01	4-16-66 RGM
	T-34711 4-16-66 REL. TO ORIGINAL
	ITEM 44: WAS 7 REQ.
02	5-4-66 RGM
	T-34711 5-4-66 REL. TO ORIGINAL

UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES & MACHINING TOLERANCES ARE: ANGLES ±

DIMENSIONS	UP TO 6 INCL.	OVER 6 TO 24 INCL.	OVER 24
FRACTIONAL	±	±	±
DECIMAL	±	±	±

~~Confidential~~ Property of

ALLIS-CHALMERS MFG. CO., Milwaukee, Wis.

RESEARCH 3341 DEPT

DR'N DSH 4-16-66 CH'D D.P.D. 4-16-66

TR'D APP'D RGM 4-16-66

FIGURE 3-2

ALLIS-CHALMERS CONTROL PANEL ASSEMBLY P/L

USED ON: 49-200-431-504, -505
49-200-495-501, -502, -503

SIMILAR TO: SCALE

SHEET 1 OF 2

49-200-549-501

3-2-3

REQ.	ITEM	DESCRIPTION	PART NUMBER
4	55	UNIRING, INSULATED, BURNDY YEC-110	MS25311-110
4 FT.	56	TUBULAR BRAID, .172 I.D. ALPHA #2168	QQ-B-575
20 FT.	57	" " .078 I.D. " " #2163	QQ-B-575
4 FT.	58	TUBING, HEAT REACTIVE (MSFC-276) .5 " 276-11BKOD25DIA	49-200-549-058
20 FT.	59	" " " " .12 " 276-11BKOD12 DIA	49-200-549-059
60	60	" " .187 I.D. x .75 LG. ALPHA FIT-350 3/16	49-200-549-060
1	61	" " " .375 I.D. x .75 LG. " FIT-350 [illegible]	49-200-549-061
60 FT.	62	LACING, .090 FLAT NYLON, BLACK, ALPHA LC-136 MIL-T-713A	49-200-549-062
11	63	TERMINAL, INSULATED SOLDERLESS, RING TONGUE, AMP #1553	49-200-549-063
60	64	" " " FLANGED SPADE, " #1560	49-200-549-064
400 FT.	65	WIRE, BLACK, UNSHIELDED B-20(19/32), ALPHA #1859/19 COLOR 2	49-200-549-065
100 FT.	66	" " " B-16(19/29) " #1855/19 " 2	49-200-549-066
YES	67	SOLDER, SN-60, QQ-S-571 TYPE RA	49-200-549-067
YES	68	FLUX, MIL-F-14256, TYPE A	49-200-549-068
1	69	LEFT HAND BRACKET	49-300-531-002

01	4-16-66	RGM
	SEE SHEET 1	
02	5-4-66	RGM
	5-4-66 REL.	

UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES & MACHINING TOLERANCES ARE: ANGLES ±

DIMENSIONS	UP TO 6 INCL	OVER 6 TO 24 INCL	OVER 24
FRACTIONAL	±	±	±
DECIMAL	±	±	±

~~Confidential~~ – Property of

ALLIS-CHALMERS MFG. CO., Milwaukee, Wis.

RESEARCH 3341 DEPT

DR'N DSH 4-16-66 CH'D D.P.D. 4-16-66

TR'D APP'D RGM 4-21-66

ALLIS-CHALMERS
CONTROL PANEL
ASSEMBLY P/L

FIGURE 3-2

SIMILAR TO SCALE SIZE

SHEET 2 OF 2

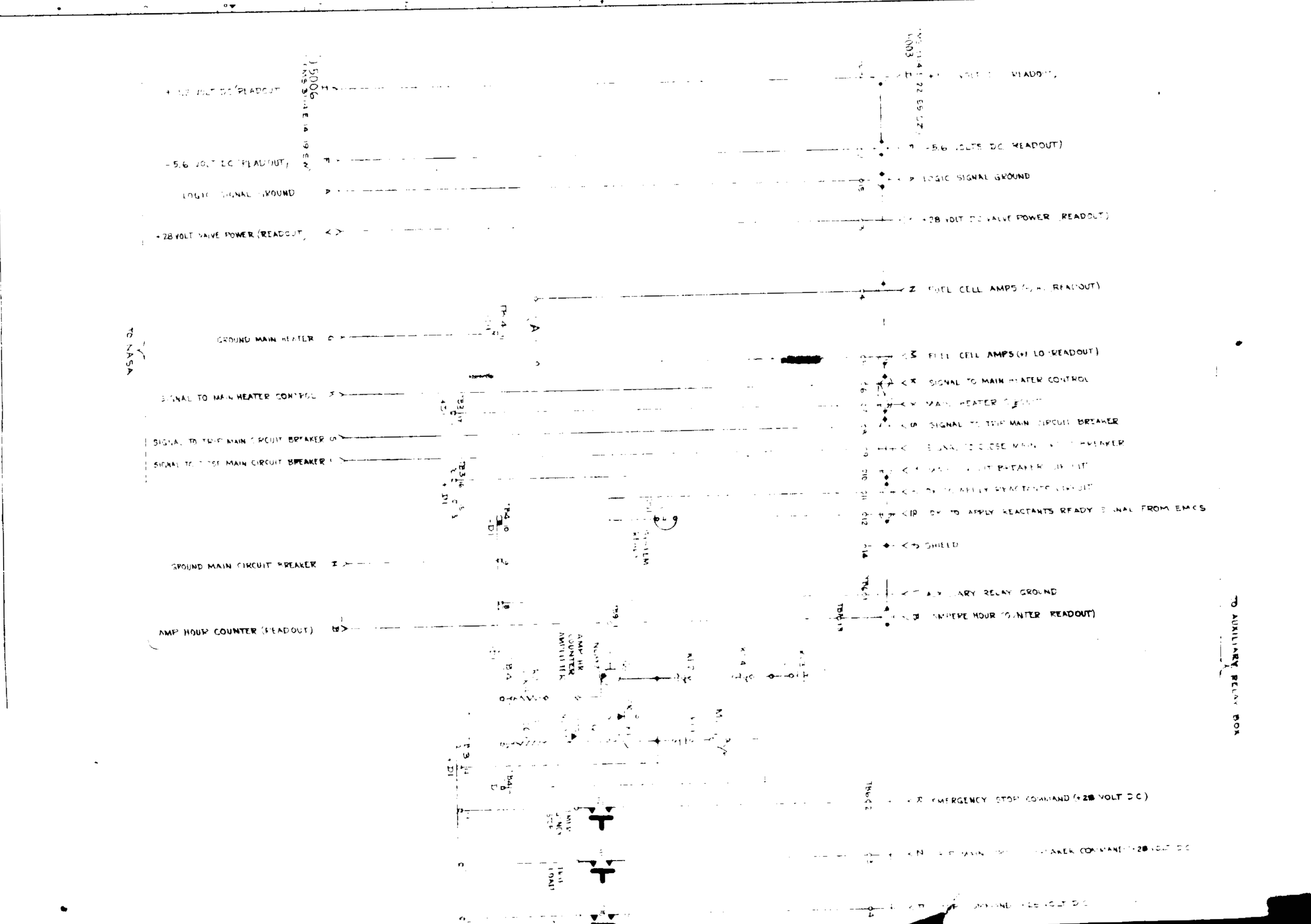
49-200-549-501

1 2 3 4

A-C MFG. CO. MILWAUKEE, WIS. FORM 8081-4

3-2-2

(G-5) LAMPS DS4
DS5, DS6
DISCONNECTED
FROM +D1 AND
CONNECTED
TO TB5-5.



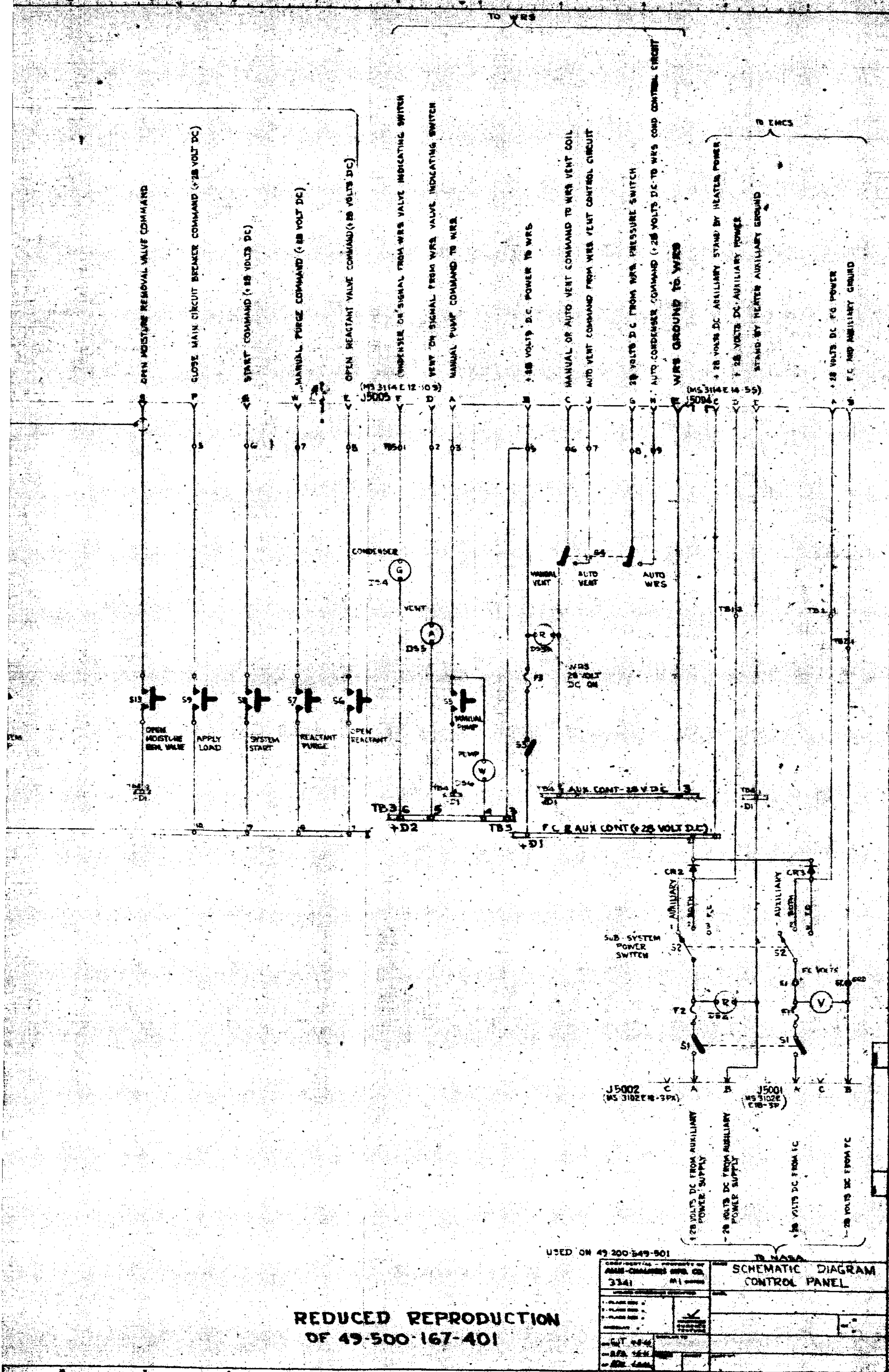
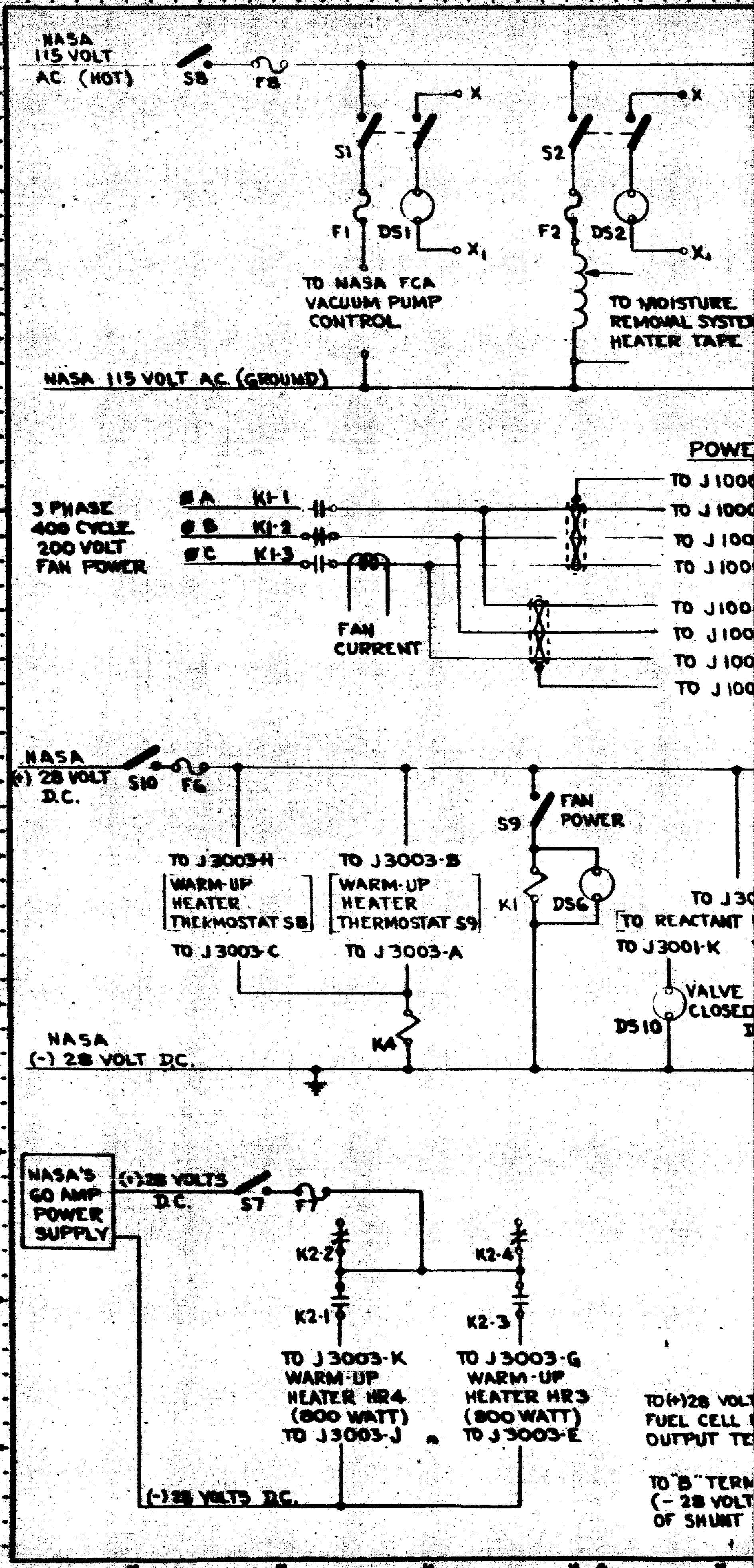
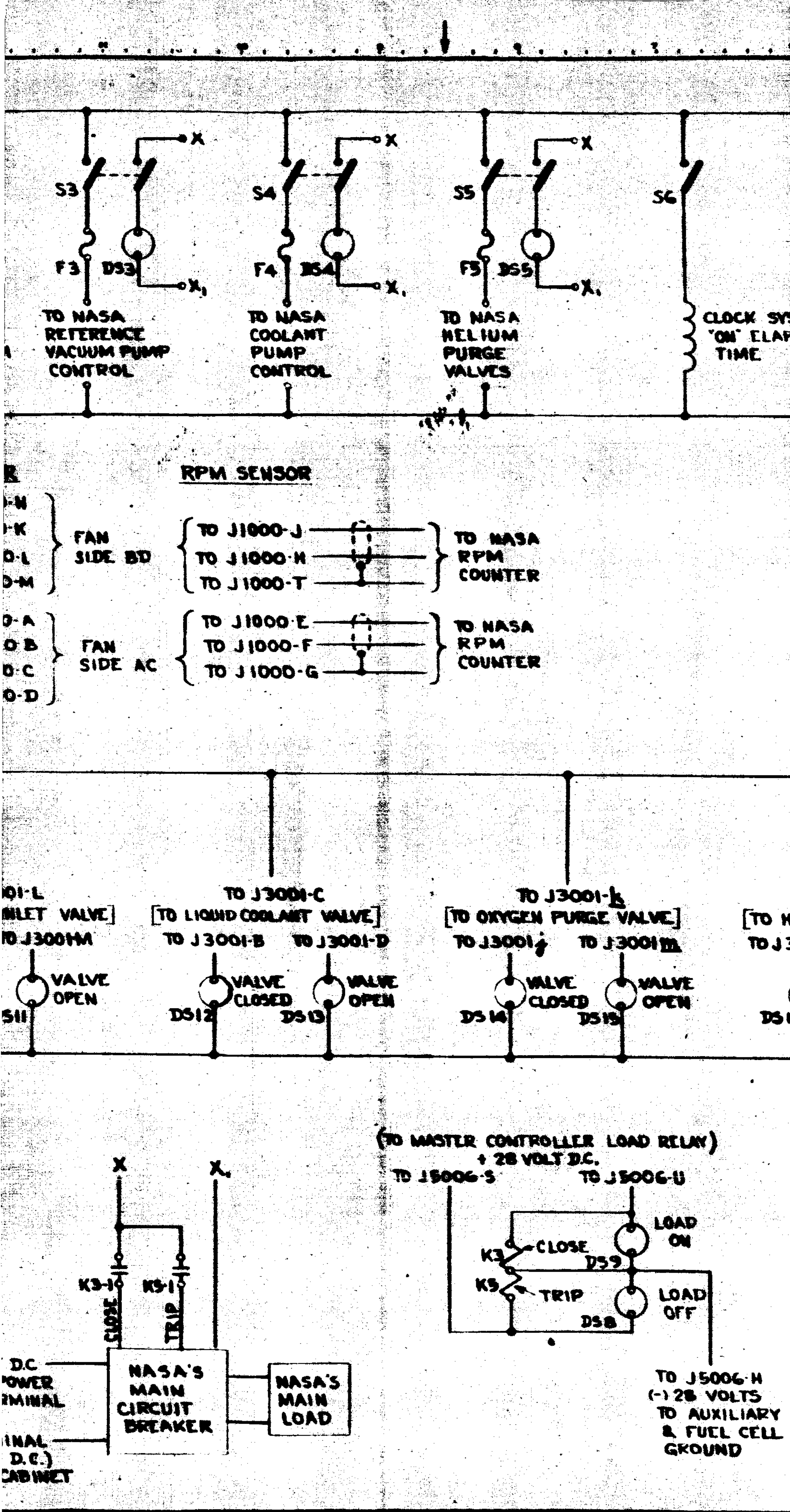

TO WRS
OPEN MOISTURE REMOVAL VALVE COMMAND
CLOSE MAIN CIRCUIT BREAKER COMMAND (+28 VOLT DC)
START COMMAND (+28 VOLTS DC)
MANUAL PURGE COMMAND (+28 VOLT DC)
OPEN REACTANT VALVE COMMAND (+28 VOLTS DC)
CONDENSER 'ON' SIGNAL FROM WRS VALVE INDICATING SWITCH
VENT 'ON' SIGNAL FROM WRS VALVE INDICATING SWITCH
MANUAL PUMP COMMAND TO WRS
+28 VOLTS D.C. POWER TO WRS
MANUAL OR AUTO VENT COMMAND TO WRS VENT COIL
AUTO VENT COMMAND FROM WRS VENT CONTROL CIRCUIT
28 VOLTS D.C. FROM WRS PRESSURE SWITCH
WRS GROUND TO WRS
TO EMCS
+28 VOLTS DC AUXILIARY STAND BY HEATER POWER
+28 VOLTS DC AUXILIARY POWER
STAND BY HEATER AUXILIARY GROUND
+28 VOLTS DC FC POWER
F.C. AND AUXILIARY GROUND
J5005
J5004
CONDENSER
VENT
MANUAL VENT
AUTO VENT
AUTO WRS
WRS 28 VOLT DC ON
OPEN MOISTURE REM VALVE
APPLY LOAD
SYSTEM START
REACTANT PURGE
OPEN REACTANT
MANUAL PUMP
PUMP
TB3
TB5
AUX CONT - 28 V D.C.
F C & AUX CONT (+28 VOLT D.C.)
SUB-SYSTEM POWER SWITCH
AUXILIARY
FC VOLTS
J5002
J5001
+28 VOLTS DC FROM AUXILIARY POWER SUPPLY
-28 VOLTS DC FROM AUXILIARY POWER SUPPLY
+28 VOLTS DC FROM FC
-28 VOLTS DC FROM FC
TO NASA
USED ON 49-200-549-501
SCHEMATIC DIAGRAM
CONTROL PANEL
REDUCED REPRODUCTION
OF 49-500-167-401

FIGURE 3-3-2

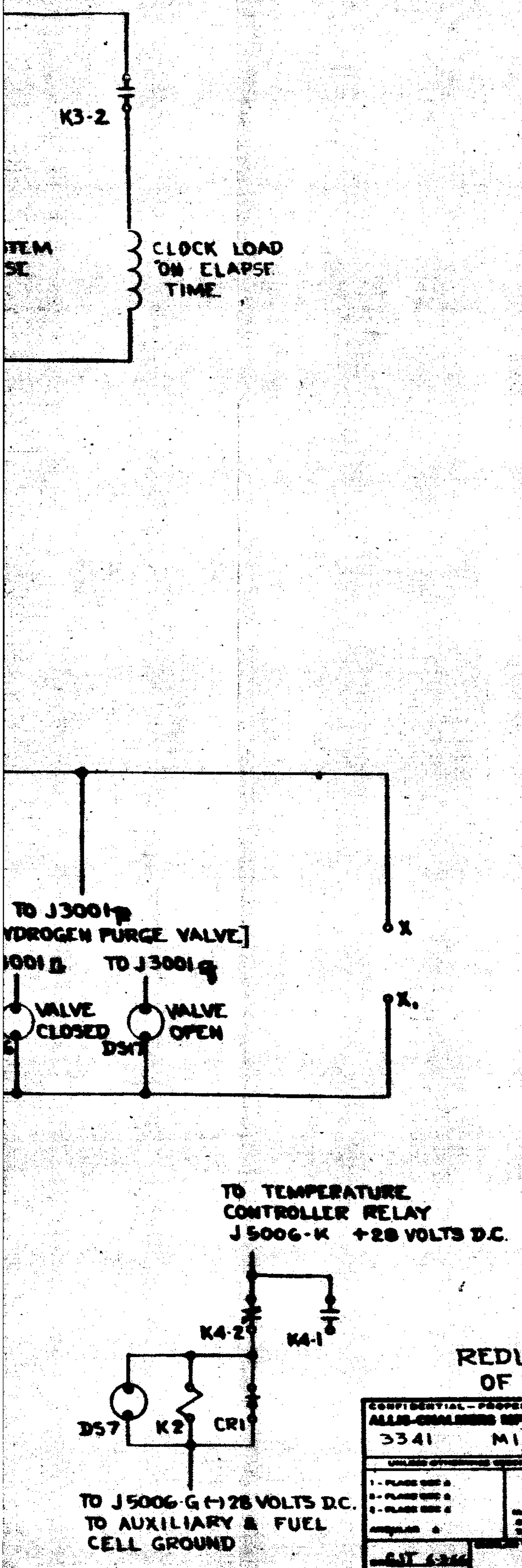


NASA 115 VOLT AC (HOT)
S8
F8
X
S1
F1
DS1
X1
TO NASA FCA VACUUM PUMP CONTROL
S2
F2
DS2
X1
TO MOISTURE REMOVAL SYSTEM HEATER TAPE
NASA 115 VOLT AC (GROUND)
POWE
3 PHASE 400 CYCLE 200 VOLT FAN POWER
ØA K1-1
ØB K1-2
ØC K1-3
FAN CURRENT
TO J100
NASA (+) 28 VOLT D.C.
S10
F6
S9
FAN POWER
K1
DS6
TO J3003-H
WARM-UP HEATER THERMOSTAT S8
TO J3003-C
TO J3003-B
WARM-UP HEATER THERMOSTAT S9
TO J3003-A
K4
NASA (-) 28 VOLT D.C.
TO REACTANT
TO J3001-K
VALVE CLOSED
DS10
NASA'S 60 AMP POWER SUPPLY
(+) 28 VOLTS D.C.
S7
F7
K2-2
K2-1
K2-4
K2-3
TO J3003-K WARM-UP HEATER HR4 (800 WATT) TO J3003-J
TO J3003-G WARM-UP HEATER HR3 (800 WATT) TO J3003-E
(-) 28 VOLTS D.C.
TO (+) 28 VOLT FUEL CELL OUTPUT TE
TO "B" TERM (- 28 VOLT OF SHUNT


S3
F3
DS3
X
X1
TO NASA REFERENCE VACUUM PUMP CONTROL
S4
F4
DS4
TO NASA COOLANT PUMP CONTROL
S5
F5
DS5
TO NASA HELIUM PURGE VALVES
S6
CLOCK SYS "ON" ELAP TIME
RPM SENSOR
FAN SIDE BD
TO J1000-J
TO J1000-H
TO J1000-T
TO NASA RPM COUNTER
FAN SIDE AC
TO J1000-E
TO J1000-F
TO J1000-G
TO NASA RPM COUNTER
INLET VALVE]
TO J3001-M
VALVE OPEN
DS11
TO J3001-C
[TO LIQUID COOLANT VALVE]
TO J3001-B
TO J3001-D
VALVE CLOSED
DS12
VALVE OPEN
DS13
[TO OXYGEN PURGE VALVE]
VALVE CLOSED
DS14
VALVE OPEN
DS15
(TO MASTER CONTROLLER LOAD RELAY)
+ 28 VOLT D.C.
TO J5006-S
TO J5006-U
LOAD ON
K3
CLOSE
DS9
K5
TRIP
LOAD OFF
DS8
TO J5006-H
(-) 28 VOLTS
TO AUXILIARY & FUEL CELL GROUND
K3-1
K5-1
CLOSE
TRIP
D.C
POWER
TERMINAL
D.C.)
CABINET
NASA'S MAIN CIRCUIT BREAKER
NASA'S MAIN LOAD

3-4-2

01 6-3-66 BPD



HIGHEST NO. USED
S-10
F-8
K-4
DS-17

REDUCED REPRODUCTION
OF 49-400-349-402

CONFIDENTIAL – PROPERTY OF ALLIS-CHALMERS MFG. CO.
3341 MI

RECOMMENDED NASA
AUXILIARY CONTROL

FIG 3-4

Liquid coolant supply available to the canister heat exchanger at a minimum rate of 150 pounds per hour .

110 volt, 60 cps power available at the NASA Test Control Panel

200 volt, 400 cps three-phase power available at the NASA Test Control Panel,

28 vdc auxiliary power available at the NASA Test Control Panel.

3.2.2 Cavity Helium Fill

Fill the three fuel cell cavities (hydrogen, oxygen, and water removal) with helium using the following procedure.

a. Apply 28 vdc auxiliary power to the EMCS.

b. Apply power to the helium purge (crossconnect) valves.

c. Open the moisture removal (cavity) valve.

d. Open the reactant inlet valve, or open purge valves if helium is supplied through purge lines.

e. Open the helium supply valves to permit helium flow into the three cavities.

f. Slowly raise the helium pressure to 5 psig. Allow 5 minutes for stabilization.

g. Return all switches and valves (Steps b through f) to their original position.

3.2.3 Canister Helium Fill

To evacuate and fill the fuel cell canister with helium to 13 psig, proceed as follows:

a. Open manual valving between the canister and the vacuum header, and evacuate the canister. Monitor the canister pressure.

b. When the canister is complely evacuated, close the manual valve between the canister and the vacuum header.

c. Raise the helium supply pressure to 30 psig.

d. Crack open the manual valving between the helium supply and the canister, and gradually fill the canister to a pressure of approximately 13 psig (28 psia on the pressure transducer output).

e. Repeat Steps a through d, then close the manual helium supply valve to the canister.

3.2.4 Coolant Fans

Start the coolant fans, and check the fan voltage and current to determine if they are within acceptable limits.

3.2.5 Liquid Coolant System

Start liquid coolant system, and check the coolant pressure and flow to insure it is within acceptable limits.

3.2.6 Water Removal Heating Tape

Apply power to the WRS heating tape and check to insure the tubing rises to the proper temperature range.

3.3 SYSTEM STARTUP (See A-C control panel Figure 3-1 (49-400-317-401), Figure 3-2 (49-200-549-501), Figure 3-3 (49-500-167-401) and NASA Control Panel Figure 3-4 (49-400-349-402).

3.3.1 Initial Conditions

After the conditions of the pre-startup are met, a normal startup will be initiated with the system supplies set as follows:

Hydrogen — Set the house regulator to deliver an outlet pressure of between 200 and 400 psia. The fuel cell hydrogen regulator is set to deliver a pressure output of approximately 37 psia over the full flow range (0. 04 to 0. 75 pounds per hour).

Oxygen — Set the house regulator to deliver a pressure of between 200 and 400 psia. The fuel cell oxygen regulator is set to deliver a pressure output of approximately 37 psia over the full flow range (0. 32 to 6. 0 pounds per hour).

Helium — Set the house regulator to deliver pressure of 40 $\pm$ 2 psia, for the WRS pump.

Liquid Coolant — applied to the fuel cell as specified in Paragraph 3. 2. 1.

Vacuum — Applied as indicated in Paragraph 3. 2. 1

Auxiliary Power — Applied to EMCS

Fan Power — ON

WRS Heater Tape Power — ON

3. 3. 2 Startup Sequence

a. Vent the moisture removal cavity into the vacuum system. Check the cavity pressure transducer to determine if the cavity has vented.

b. Press the System Start switch. This applies power to stand-by heaters (50-watt each - 100-watt total) and turns ON the warm-up heaters (800 watt each - 1600 watt total) providing the 1600 watt switch is ON.

c. Monitor the fuel cell stack warm-up until the operating temperature ($185^{o}F$) is reached. The heater is controlled by a stack thermister to automatically cut-out at $185^{o}F$. The individual heaters are protected by over-temperature thermostats on the heater surfaces set for $250^{o}F$.

Note: For initial startup, allow the system to stabilize and monitor the performance of the temperature controller for one hour.

d. After fuel cell has reached its operating temperature, the "System Ready Light" will come ON, and the reactant inlet valve can be opened to allow hydrogen and oxygen enter the reactant cavities.

Note: During initial checkouts and until sufficient testing has been conducted to demonstrate system operational response and stability during startup, it would be desirable to gradually buildup the reactant pressures in the hydrogen and oxygen cavities rather than applying full cavity pressures instantaneously. This may be accomplished by manually controlling pressure buildup using the reactant supply regulators.

1. With both the hydrogen and oxygen supply regulators shutoff, press the Open Reactant button and check that the reactant inlet valve is open (light indication).
2. Slowly bring up the hydrogen and oxygen supply pressures, simultaneously using the supply regulators. Maintain hydrogen and oxygen pressures with 2 psi of each other during this procedure.
3. When rated cell pressure (37 psia) is reached, the fuel cell regulators will maintain this pressure and the supply pressures can be set as indicated in Paragraph 3. 3. 1 "Initial Conditions"

e. Check the hydrogen and oxygen pressure transducers. Both transducers should indicate 37 ± 1 psia.

f. Check that the water removal pipe is hot, approximately 190°F.

g. Purge the reactant cavities three successive times to clean out the helium or any other inerts. This is accomplished by manually closing the reactant inlet supply valves feeding the reactant inlet valve (since reactant inlet valve cannot be closed manually after being open), then opening the hydrogen and oxygen purge valves. Then refill the reactant cavities. Repeat the purge cycle until a total of three purges have been accomplished. During these operations, be sure to follow the procedure in the note under Step d, on page 3-5.

h. Check the individual cell voltages. Should any cell voltage be less than 1.0 volt, two additional manual purges are permitted to attempt bringing up the individual cell voltage.

i. Monitor the Total Fuel Cell Voltage. The total open circuit voltage should read 35 volts, or more.

j. Check the canister pressure to insure it is 40 $\pm$ 2 psia. If it is not, fill to the required pressure.

k. Check to insure that the WRS manual by-pass switch (Manual Vent-Auto) is in the "AUTO" position unless open loop tests are planned.

3.3.3 Switching Auxiliary Power To The Fuel Cell Output

After the fuel cell is warmed up to its operating temperature, the auxiliary power may be switched from external power to fuel cell power, or to Fuel Cell and Auxiliary power (both) in which case the EMCS will "Automatically Select" the source with the higher voltage.

3.4 OPERATION UNDER LOAD

(See A-C control panel Figure 3-1 (49-400-317-401), Figure 3-2 (49-200-549-501), Figure 3-3 (49-500-167-401) and NASA Control Panel Figure 3-4 (49-400-349-402).

3.4.1 Initial Conditions

Initially, the system is at operating temperature with an open circuit voltage of 35 volts or more. Reactant supplies to the fuel cell are regulated to specified values, and all pressures, individual cell voltages, and temperatures are normal. The auxiliary dc power may be supplied from the fuel cell or from an external source, as desired, to meet specific test requirements. The RPM sensors must indicate that both coolant fans are running, and the liquid coolant pressure transducers must indicate that coolant is available.

CAUTION: The fuel cell should not be held in the hot, unloaded condition (total load less than 200 watts) for more than three hours at any one time. Refer to Paragraph 3.6.2 if longer standby periods are contemplated.

3.4.2 External Load Circuits

Since the external load circuits are being furnished by MSFC, their description does not form a part of this manual. A pilot relay must be provided to control the external load circuitry as the "Load" relay in the EMCS will only handle 1 ampere maximum.

3.4.3 Load Application

To apply load to the fuel cell system, push the "Apply Load" Button. The load "ON" signal will also initiate an automatic cavity purge cycle whenever it is actuated.

3.4.4 Normal Operating Parameters

After each incremental load change, the following operating parameters should be monitored to insure normal operation:

Module Temperature	—	190^{o} - $200^{o}F$
Hydrogen Inlet Pressure	—	37 $\pm$ 1.0 psia
Oxygen Inlet Pressure	—	37 $\pm$ 1.0 psia
Moisture Removal Cavity Pres.	—	Varies automatically to maintain proper KOH concentration (See Figure 3-5)
Canister Helium Pressure	—	40 $\pm$ 2 psia
Load Current	—	Not to exceed 75 amperes continuous, and 150 amperes for 30 seconds.
Total Fuel Cell Voltage	—	See Figure 3-5
Reactant Gas Purge	—	
Frequency	—	Every 128 ampere-hours
Duration	—	6 seconds
Flow Rate:	—	H_2 0.69 lb/hr.
		O_2 5.47 lb/hr.

3.4.5 Automatic Operation

The system will now operate automatically under load and during load changes as long as reactant gases are supplied and all critical parameters are under control. The individual cell voltages should be monitored at least every one-half hour. Should any individual cell voltage fall below 0.5 volts, it is recommended that a manual purge cycle of six seconds duration be initiated. If the individual cell voltage does not remain above 0.5 volts under load, a second manual purge cycle may be initiated. However, to avoid drying-out the cell, only two manual purges are recommended. If the cell voltage cannot be brought up by purging, a cell depressurization cycle should be performed as follows:

a. Remove all load from the fuel cell system.

b. Close the reactant inlet supply valves.

c. Monitoring the reactant pressure transducers, apply a manual purge until the pressures drop to atmospheric.

d. Close the purge valves, open the reactant inlet valve and reapply reactants to the fuel cell.

e. Reapply a load "ON" signal to the EMCS.

NOTE: If after depressurization, the cell voltage fails to rise above 0.5 volt under load, shut down the fuel cell system and immediately notify Allis-Chalmers.

3.5 LOAD REMOVAL OPERATION (See A-C control panel Figure 3-1 (49-300-317-401), Figure 3-2 (49-200-549-501), Figure 3-3 (49-500-167-401) and NASA Control Panel Figure 3-4 (49-400-349-402) The "Drop" load or "Trip" load function can be initiated at any time during normal operation by pushing the "Trip Load" Button. This will result in the following:

a. The external electrical load on the fuel cell system will be dropped.

b. The moisture removal valve will close and remain closed until a load "ON" signal or a manual cavity valve signal is applied.

All other fuel cell system controls will remain operable and the external load may be reapplied by providing an "Apply Load" signal to the EMCS. Auxiliary DC power will continue to be supplied by the fuel cell if the system controls are so set.

As stated in Paragraph 3. 4. 1, the Load "OFF" condition should not be maintained for longer than 3 hours at any one time.

3.6 SYSTEM SHUTDOWN, STANDBY, AND STORAGE (See A-C control panel Figure 3-1 (49-400-317-401), Figure 3-2 (49-200-549-501), Figure 3-3 49-500-167-401) and NASA Control Panel Figure 3-4 (49-400-349-402).

3.6.1 System Shutdown

To shut down the fuel cell system, provide a system stop signal to the EMCS. The following actions will occur:

a. The external electrical load on the fuel cell system will be dropped, if the fuel cell is in a load "ON" condition, and Step b Paragraph 3. 5 will thereby take place.

b. The reactant inlet valve will close, and shut off the supply of hydrogen and oxygen to the fuel cell.

CAUTION: Manually reopen the reactant inlet valve and reestablish the cavity pressures and maintain cavity pressure balance within 2 psi. The system can be held at open circuit for a short period (6 hours) in this manner or the cavities can be filled with helium in the case of prolonged shutdown.

c. The System Stop signal also opens the circuit to the stack heater controller. The warmup and stand-by heaters cannot be energized until the System Start signal is again applied.

3.6.2 System Standby at Operating Temperature

After a System Stop signal has been applied and the actions indicated in Steps a through c above have occurred, it is possible to hold the system at approximately operating temperature by performing the following: Apply a "Start" signal which will close the heater circuit. The helium circulating fans must continue to operate. The fuel cell module may be held in this condition for a period not to exceed 6 hours. It will be necessary, however, to continuously monitor the fuel cell so that the following conditions are met.

a. The fuel cell temperature as indicated by thermocouples should not exceed 200°F.

b. All external auxiliary power must be maintained.

c. Assure that water removal heater tape is energized and maintaining the water removal piping temperature. (This is to allow immediate operation when desired instead of requiring a warm-up period).

3.6.3 Prolonged Shutdown

For any period exceeding 6 hours, it will be necessary to complete system shutdown, and to flood all the cavities with helium according to the following:

a. Shut down the helium circulating fans.

b. Close any manual valves in the hydrogen and oxygen supply lines to the fuel cell module.

c. Apply a manual purge signal until the hydrogen and oxygen cavities are at atmospheric pressure.

d. Close the purge valves.

e. Perform a cavity helium fill by following Steps b through g of Paragraph 3.2.2.

f. Check the helium pressure in the fuel cell canister; if it is less than 13 psig follow Steps c and d, Paragraph 3.2.3 to bring the pressure back up.

g. Switch off all power, and pumps which are used in the test setup.

The system is now secure and may be left inoperative for a prolonged period as long as helium pressure is maintained in the cavities and canister. It is recommended that these pressures be monitored once every hour for the first 24 hours and once every 8 hours thereafter. The helium pressure should be brought back to nominal values when the following minimums are reached:

a. The canister pressure drops to 8 psig.

b. The three cavity pressures drop to 3 psig.

3.6.4 System Storage

The fuel cell stack may be stored indefinitely in its shipping container in a protected area with an ambient temperature of 49°F or higher.

All other components may be stored in protected, but unheated, areas, provided adequate steps are taken to prevent condensation on the components.

3.7 ABNORMAL OPERATION AND EMERGENCY SHUTDOWN

Abnormal operation is defined as any operating condition in which one or more of the critical control parameters exceeds its normal control range. The critical control parameters, their normal range and action to be taken if the control band is exceeded, is presented briefly in this section.

3.7.1 Stack Temperature

The normal control range is 195° $\pm$ 5°F as sensed by the thermister located between plates 80 and 83 on the fuel cell stack. A spare thermister is provided in the same block.

a. Over-Temperature — Over-temperature may be detected by monitoring the thermocouples that form part of the test instrumentation. On an over-temperature indication, check for the following:

1. loss of liquid coolant,

2. loss of helium circulating fans,

3. loss of helium from the canister.

The fuel cell should be shut down immediately if a stack temperature of 220°F is reached. Below this temperature, the fuel cell may be operated up to 3 hours while the cause of the over-temperature is being investigated.

b. Under-Temperature — Under-temperature operation is indicated by a gradual deterioration of cell performance under load, but represents no immediate safety or performance problem. It may be caused by overcooling by the liquid coolant system, or under-heating when operating at light loads in cold environments. To determine the cause, the liquid Coolant Valve should be closed. Monitor the stack temperature for effect. If the temperature begins to rise, a fault exists somewhere in the cooling system. If the temperaature remains low, the fault is probably in the heaters or heater controls; this should be checked with the fuel cell system shutdown.

3.7.2 Total Fuel Cell Voltage

The normal fuel cell voltage will vary with load, as shown in Figure 3-5 and with fuel cell load life. The operator should be alert primarily for voltage changes during operation at constant load. Should the total voltage change 1/2 volt in 2 hours under a constant load condition, a complete survey of the individual cell voltages should be made.

A decreasing total cell voltage under constant load conditions may be caused by several factors such as:

a. Accumulation of inerts in the cavities,

b. Decrease in reactant supply.

c. Improper operation of the water removal subsystem,

d. Fuel cell stack temperature too high or too low. (See Paragraph 3. 7. 1)

Upon detection of an abnormal voltage output drop, the external fuel cell load should be removed, and the open circuit voltage on the individual cells should be checked.

a. Accumulation of Inerts — If the voltage change is due to an accumulation of inerts within one or more of the individual cells, the total voltage will usually show a gradual decrease over a period of hours. The operator may perform two manual purge cycles to bring all the cell voltage to a minimum of 1.0 volts open circuit.

b. Reactant Cavity Pressures — The cavity pressure regulators are set to maintain the hydrogen and oxygen cavities at 37 ± 1 psia over the fuel flow range. Each cavity pressure is monitored by a pressure switch set to close the reactant inlet valve and to drop the main fuel cell load at a pressure of 44.5 ± 0.5 psia.

   Should the reactant inlet valve close during the operation, the load should be removed and the reactant cavity pressures should be checked immediately. If high reactant inlet pressure is indicated as the cause of the inlet valve closure then the cavities should be manually purged until atmospheric pressure is attained.

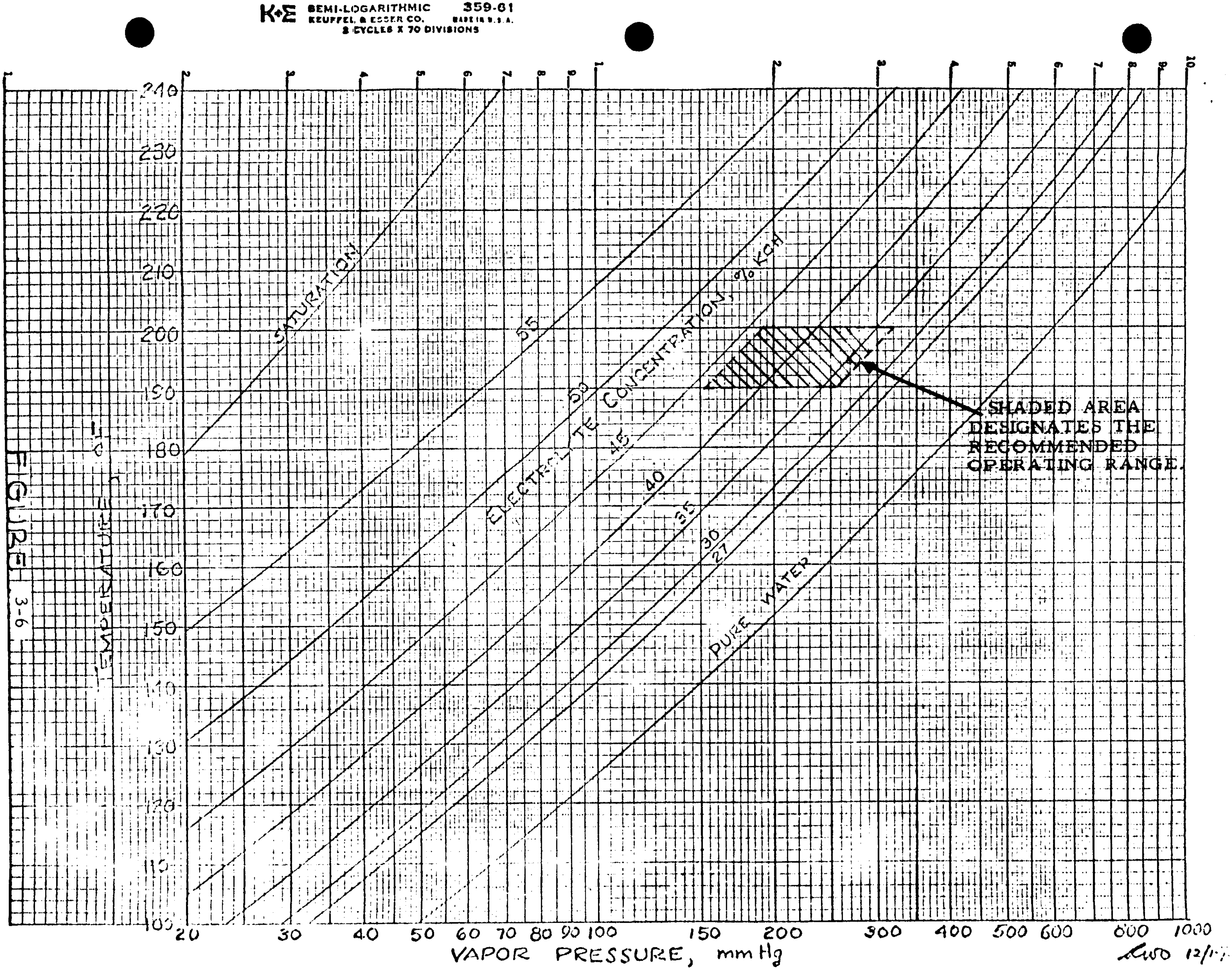
   Close the manual valves in the reactant inlet lines and flood the cavities with helium to 5 psig. Then check the operation of the reactant gas pressure regulators before restarting the system.

c. Moisture Removal - Moisture removal subsystem malfunctions may result in a decrease in cell voltage either due to excessive wetting of the cell or excessive cell drying. If the moisture removal valve stays closed, the cell will accumulate too much moisture and the electrolyte will become diluted. To determine if this is the problem, reduce the load to reduce the probability of causing permanent damage and take readings of the cavity pressure and stack temperature . Compare these readings to the allowable operating range as shown on Figure 3-6. Should over wetting prove to be the cause of decrease in cell voltage, the moisture removal valve should be opened and the change in cavity pressure observed. If the malfunction appears to be on the cavity controller, the fuel cell should be shut down and Allis-Chalmers should be notified immediately.

Excessive cell drying can occur if the moisture removal valve is open too long. This condition can be corrected by a period of low load operation with the moisture removal valve closed. Excessive drying can be determined by observing the action of the moisture removal valve, monitoring the cavity pressure, and observing cell voltage for a period of 1 to 2 hours while operating at low load 20 amp). The information obtained should be compared with Figure 3-6. Should cell drying be indicated, the Allis-Chalmers Project Manager or his site representative should be contracted for a detailed corrective procedure.

3.7.3 Canister Pressure

Canister over-pressure protection is provided by a relief valve set to open at a pressure of 45 psia. Canister pressure is monitored by a pressure transducer. Since canister pressure is controlled manually,



K+E SEMI-LOGARITHMIC 359-61
KEUFFEL & ESSER CO. MADE IN U.S.A.
2 CYCLES X 70 DIVISIONS
SATURATION
55
50
45
40
35
30
27
ELECTROLYTE CONCENTRATION, % KOH
PURE WATER
SHADED AREA DESIGNATES THE RECOMMENDED OPERATING RANGE.
TEMPERATURE
240
230
220
210
200
190
180
170
160
150
130
20 30 40 50 60 70 80 90 100 150 200 300 400 500 600 1000
VAPOR PRESSURE, mm Hg

FIGURE 3-6

it should be monitored periodically and adjusted as necessary to maintain a pressure of 40 ± 1 psia during normal operation.

3.7.4 Loss of Auxiliary Power

If loss of either the 28 vdc or the auxiliary power 200 v, 400-cycle fan power is indicated, the fuel cell should be shut down immediately. Since the reactant inlet valve requires power to close, it is possible to lose auxiliary power and have the reactant inlet valve remain open. Therefore, the first step after loss of auxiliary power is to close the manual valves in the reactant supply lines, and to verify the position of the reactant inlet valve.

3.7.5 Emergency Stop

An Emergency Stop signal will perform the following functions:

a. Close the reactant inlet valve,

b. Drop the external load,

c. Interrupt the heater circuit,

d. Close the moisture removal valve,

The Emergency Stop signal should be used to shut down the fuel cell system any time a malfunction is suspected or a safety problem exists. The Emergency Stop performs essentially the same functions as the System Stop, but it by-passes some of the control system interlocks; its use, therefore, should be limited to emergency conditions. The normal startup procedure should be utilized following an emergency stop.

SECTION IV

SUBSYSTEM DESCRIPTION

4.1 FUEL CELL STACK SUBSYSTEM (FCSS)

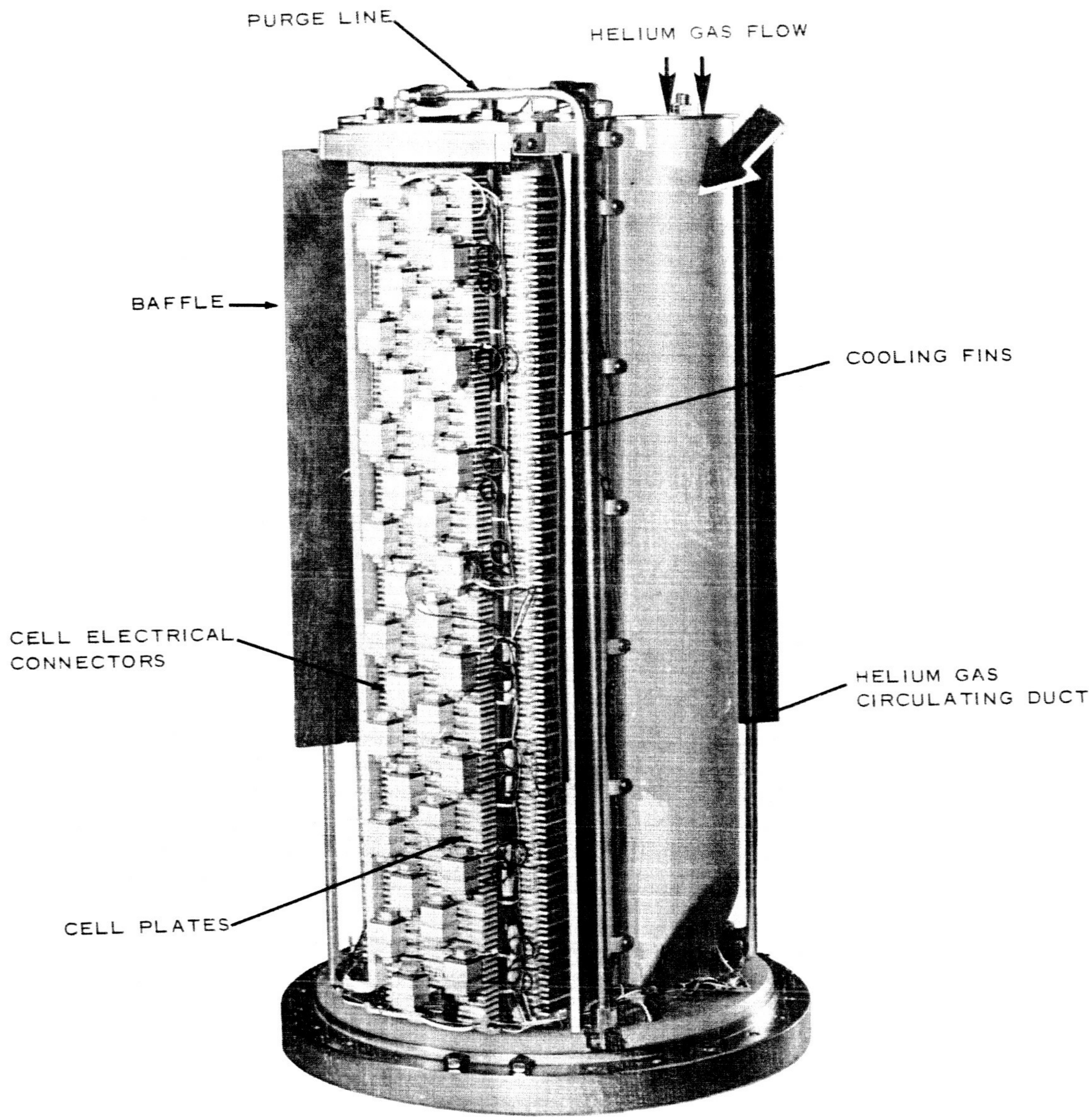
The Fuel Cell Stack Subsystem (FCSS) is the subassembly that converts chemical energy to electrical energy, producing heat and potable water as by-products of the reaction.

4.1.1 Description

The FCSS consists of 33, two-cell parallel connected, sections. The 33 sections are electrically connected in series to produce a nominal 29 vdc output capable of supplying 2,000 watts. Each cell has an effective electrochemical reaction area of 0.20 $feet^2$. An asbestos capillary matrix facing the hydrogen electrode provides for removal of the by-product water. The stack subassembly is shown in Figure 4-1. An exploded view of the cell construction is shown in Figure 4-2.

The construction consists of individual cells stacked in a manner that results in common oxygen and water plates for adjacent cells. The electrical connections are provided at both ends of the hydrogen and oxygen plates to minimize the voltage drop due to plate and connector resistance. In addition, electrical connections are silver or gold plated to minimize contact resistance.

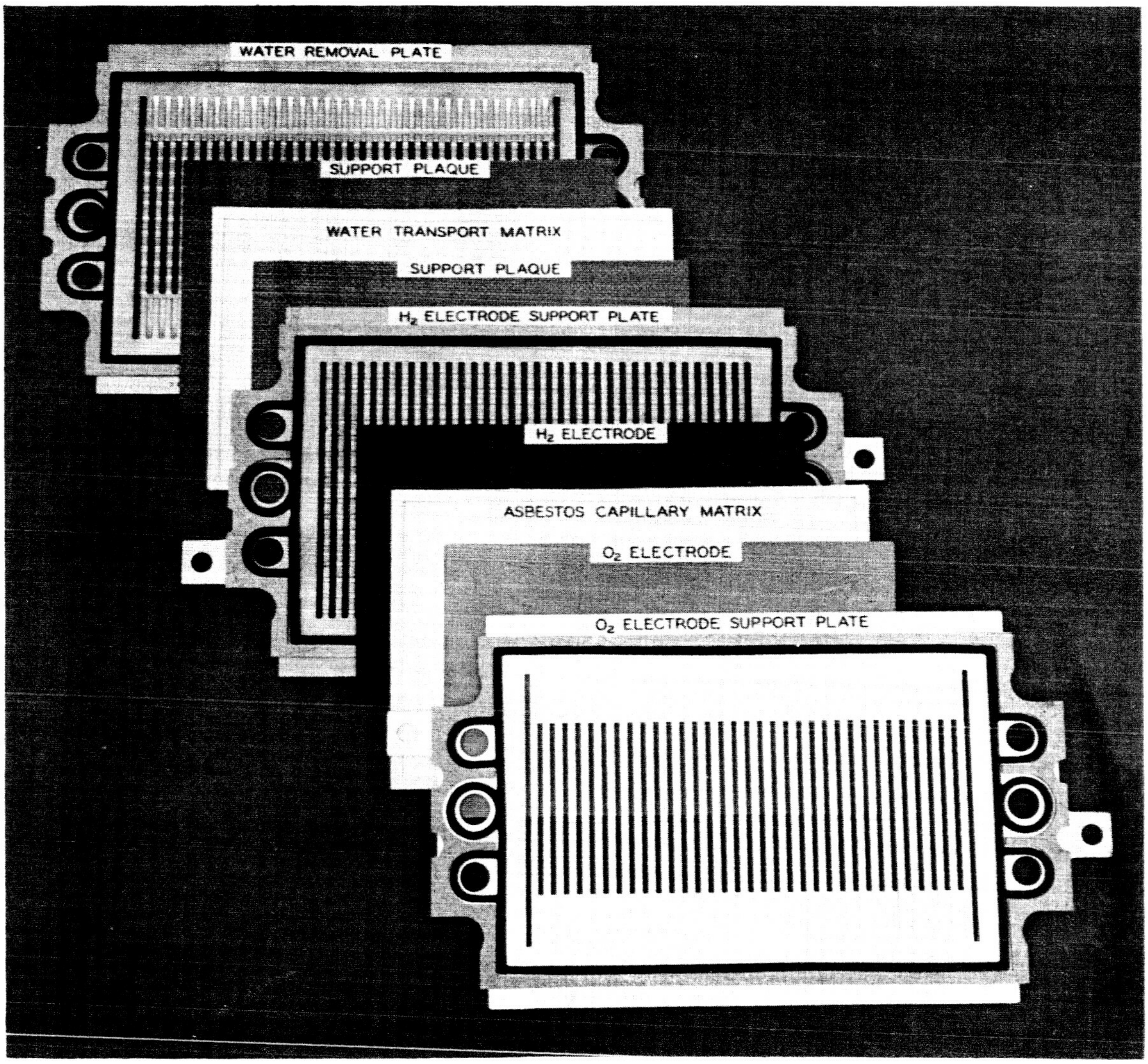
The reactants are supplied to the cell plates, and the by-product water is removed,through the main manifolds formed by holes and seals at the end of the plates. The reactants flow from the main manifold holes through electro-discharge machined (EDM) slots in the plates to grooved passages



FUEL CELL STACK. The stack, the power producing element of the system, consists of 33 two-cell sections. Each cell has an effective electro-chemical reaction area of 0.2 square foot. By-product water is removed from the stack in the vapor state using a simple and characteristically stable static moisture removal technique. Plastic ducts (arrow) direct coolant gas over the cell edges for thermal conditioning.

Figure 4-1

ALLIS-CHALMERS



CELL CONSTRUCTION. The cell consists of two porous electrodes separated by an asbestos capillary matrix, which holds the aqueous potassium hydroxide (KOH) electrolyte. The electrode support plates provide passageways for distributing the reactants to the cell, and serve as current collectors and terminals for the electrodes. Product water is removed via the water transport matrix and the water removal plate as water vapor. When assembled, the plates extend slightly beyond the cell, thus serving as cooling fins for removing waste heat.

Figure 4-2

on the plate surfaces, providing uniform distribution of the reactants over the electrode surface. By-product water is removed through similar passages and slots.

Heat from the cell reactions is removed by conduction through the metal sections of the cell plates to cooling fins located on two sides of the plates, and with the by-product water vapor.

The cell plates are made of a high thermal conductivity magnesium alloy, and are electroless nickel plated; the oxygen plates have an additional plating of gold.

The seal for containing the reactants and by-product water vapor in the cells is formed by compressing the KOH impregnated asbestos capillary matrix between the plates. A elastomer seal is used to contain the liquid KOH and to contain the reactants and water vapor in the common manifold passageways. An insulating spacer material, 0.065 inch thick, surrounds and contains the elastomer seal. This spacer controls the compression on the cells, moisture removal matrix, and the elastomer seals.

The cells are sandwiched between thermal insulation and end plates and are held in compression by tie rods.

4.2 REACTANT CONTROL AND CONDITIONING SUBSYSTEM (RCCS)

The Reactant Control and Conditioning Subsystem (RCCS) has several functions. It maintains constant hydrogen and oxygen (reactant) pressures within the Fuel Cell Stack Subassembly (FCSS), maintains reactant flow rates as demanded by the FCSS, provides a means of purging the FCSS of inert gas contaminants, and prevents over-pressurization of the FCSS. The reactants are supplied to the RCCS at pressures between

200 and 400 psia, at temperatures between 0 and 150°F, and with purity requirements as noted in Paragraph 3.2.1.

4.2.1 Description

The RCCS consists of three solenoid valves: two pressure regulators, two absolute pressure switches, two absolute pressure transducers, ~~two reactant pre-heaters~~, and the associated plumbing. These components are functionally arranged as indicated schematically in Figure 4-3. The inlet solenoid valve isolates the Fuel Cell Stack from the reactant supply during non-operation. The pressure regulators maintain constant reactant pressures within the FCSS with a tolerance of $\pm$ 1 psi at a set pressure of 37.0 psia. The absolute pressure switches prevent damaging pressure extremes within the FCSS in order to maintain reactant purity within the cell. The pressure transducers monitor hydrogen and oxygen pressures to the FCSS The Inlet solenoid valve is equipped with supervisory contacts from which valve position can be monitored. The reactant pre-heaters are used to bring both the oxygen and hydrogen up to operating temperature.

4.3 THERMAL CONTROL AND CONDITIONING SUBSYSTEM (TCCS)

The TCCS is designed to perform the following function:

a. Bring the fuel cell from 0°F up to 185°F within one hour,

b. Maintain fuel cell operating temperatures at 195 $\pm$ 5°F throughout the operating period,

c. Monitor the canister pressure and provide canister over pressure protection.

4.3.1 Description

A schematic representation of the TCCS is shown in Figure 4-4, and Figure 4-5. Functions of the major TCCS components are as follows:

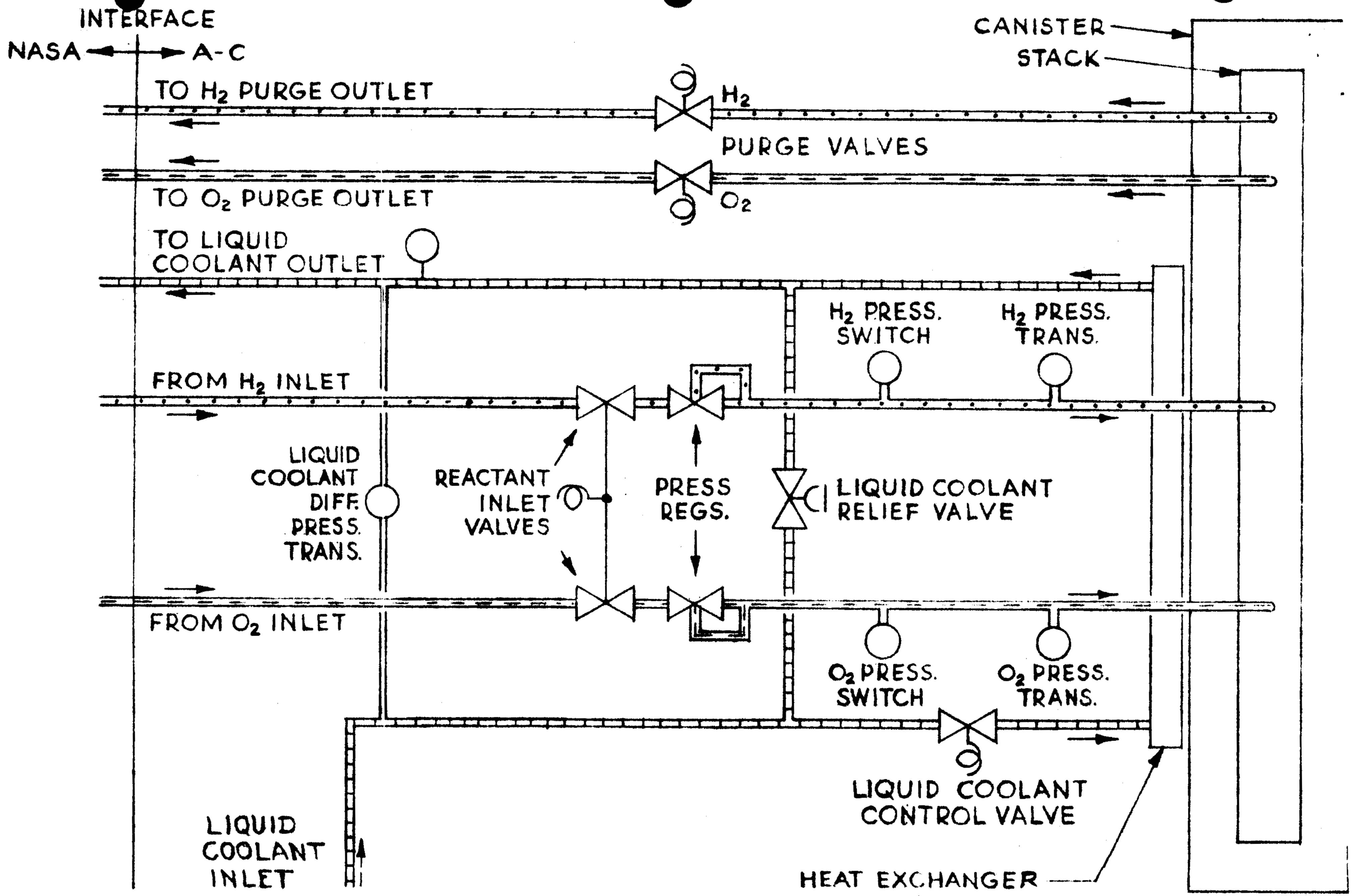


FIG. 4-3 REACTANT CONDITIONING CONTROL SUBSYSTEM (RCCS)

THERMAL CONDITIONING AND CONTROL SUBSYSTEM
(TCCS)

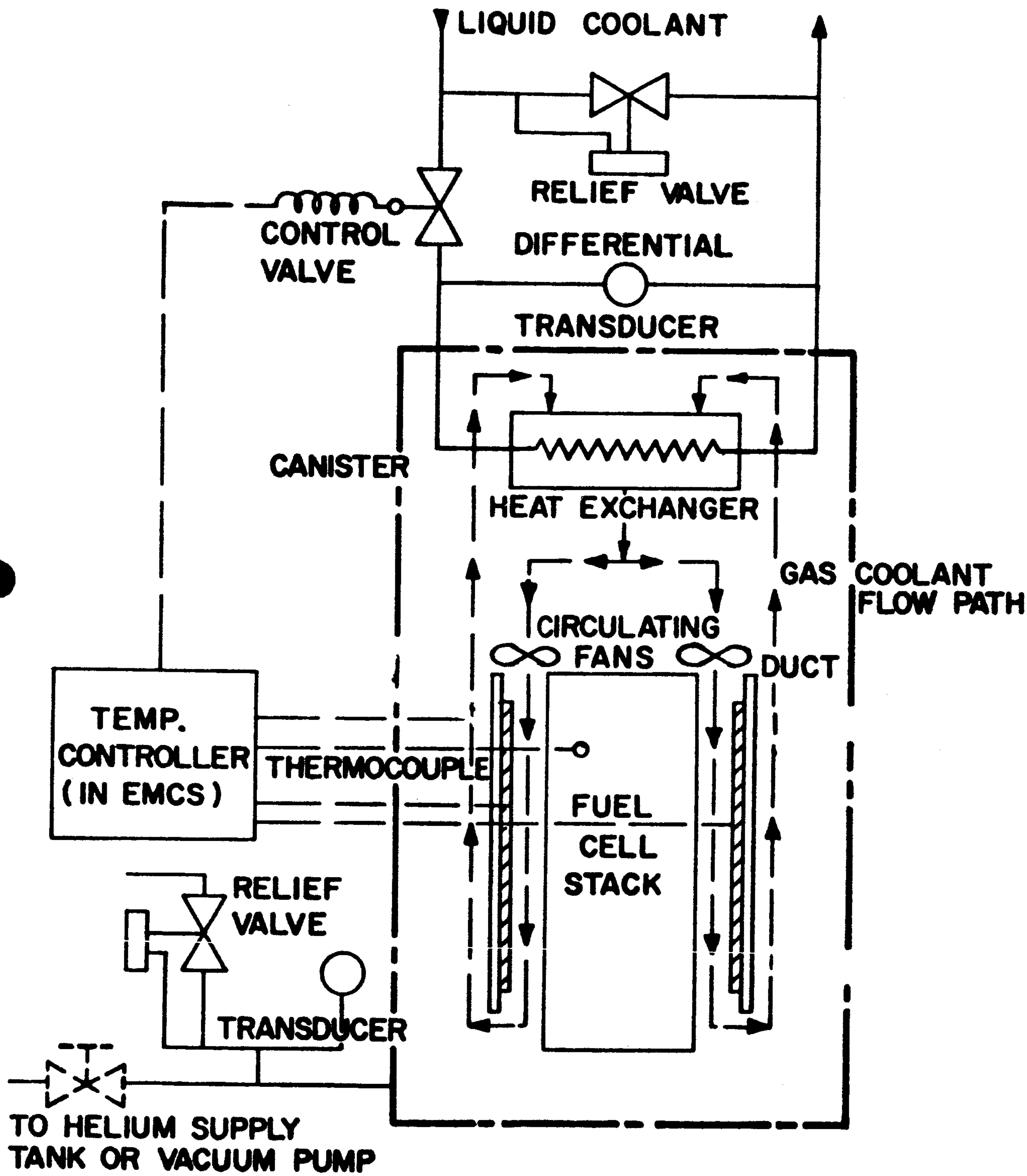
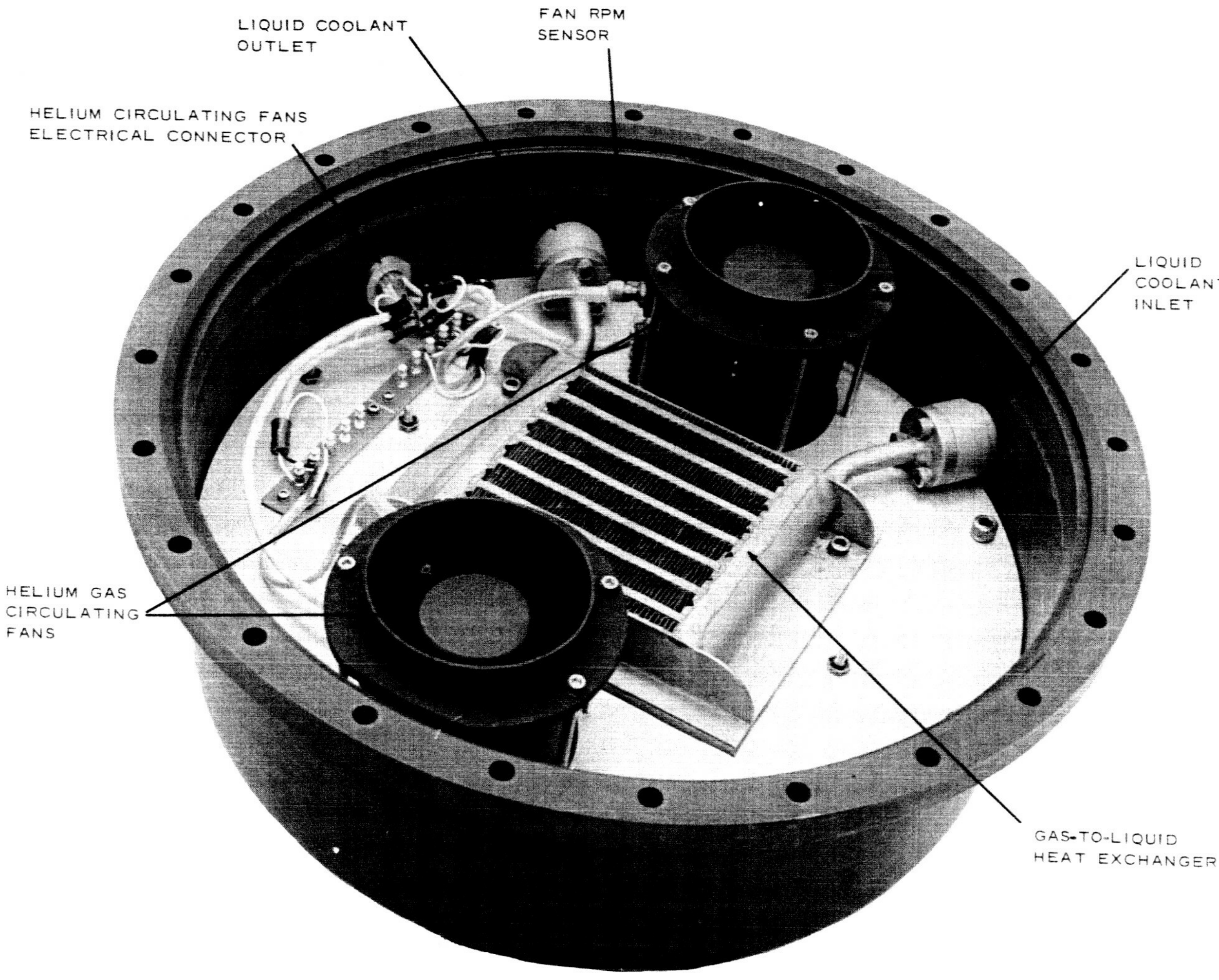


FIGURE 4-4

ALLIS-CHALMERS



THERMAL CONTROL AND CONDITIONING. Circulating fans and a gas-to-liquid heat exchanger, mounted in the canister dome, provide thermal conditioning for the stack. The fans circulate helium gas through distribution ducts, over protruding cell fins, and then through the heat exchanger. Stack temperature is maintained by controlling the flow of liquid coolant through the heat exchanger.

Figure 4-5

a. Warmup — The warm-up heaters (two 800-watt heaters controlled by the EMCS, powered by NASA) and the stand-by heaters (two 50-watt heaters controlled by the EMCS, powered by the EMCS) heat the helium gas in the canister, and the helium gas is circulated around the FCSS by the fans. This operation transfers thermal energy from the warm-up heaters and stand-by heaters to the FCSS and brings it up to operating temperature. A thermostat senses stand-by heater surface temperature and controls the power input to these heaters, through a solid state switch, such that the surface temperature of the stand-by heaters never exceeds 250°F. The temperature controller senses FCSS temperature when that temperature reaches 185°F, power to the warm-up heaters stand-by heaters is shut off. NOTE: Both type heaters are parallel controlled by the EMCS. However, the 800-watt heater surface temperature can be controlled by NASA through the 800-watt thermostats.

b. Operating — After the FCSS reaches a temperature of 195°F, the TCCS must remove the excess heat generated by fuel cell operation. To accomplish this, the temperature controller senses FCSS temperature through a thermistor and controls the flow of liquid coolant through the heat exchanger, shown in Figure 4-4 by opening or closing the liquid coolant control valve. The liquid coolant control valve opens when FCSS temperature is maintained at 195 ± 5°F. The helium gas in the canister is circulated around the FCSS and through the heat exchanger by continuous operating fans. The helium gas picks up heat from the FCSS and transfers it to the liquid coolant in the heat exchanger. The liquid coolant, in turn, transports the heat out of the canister to the liquid coolant sink where it is dissipated.

If the level of fuel cell operation is such that FCSS temperature drops below 185°F, the TCCS will go into the warm-up operation to maintain operating temperature. If one desires, the 800-watt heaters can be shut off and additional heating will be accomplished by the 50-watt heaters.

c. Canister Pressurization — The fuel cell canister is evacuated and filled with helium gas to a pressure of 40 $\pm$ 2 psia. The operation capacity of the TCCS is dependent upon the characteristics of this helium gas, which is used as a secondary coolant in the TCCS.

Therefore, a method is provided for maintaining canister pressurization as shown in Figures 4-4 and 4-5. A relief valve provides over-pressure protection and a pressure transducer provides a method of monitoring. A manually operated valve, located on the opposite side of the system interface, is used for evacuation and fill.

4.4 MOISTURE REMOVAL SUBSYSTEM (MRS)

The Moisture Removal Subsystem (MRS) maintains water removal cavity pressure (utilized in the Static Moisture Removal Concept) equivalent to the water vapor pressure exerted by the most concentrated KOH solution desired in the FCSS water cavity. The regulator opens the valve and vents water vapor from the fuel cell if the cavity pressure exceeds this value.

4.4.1 Description

The design uses a solenoid operated water cavity valve actuated by an electronic temperature compensated controller that receives its signal from a pressure transducer. A schematic diagram of the subsystem is shown in Figure 4-6.

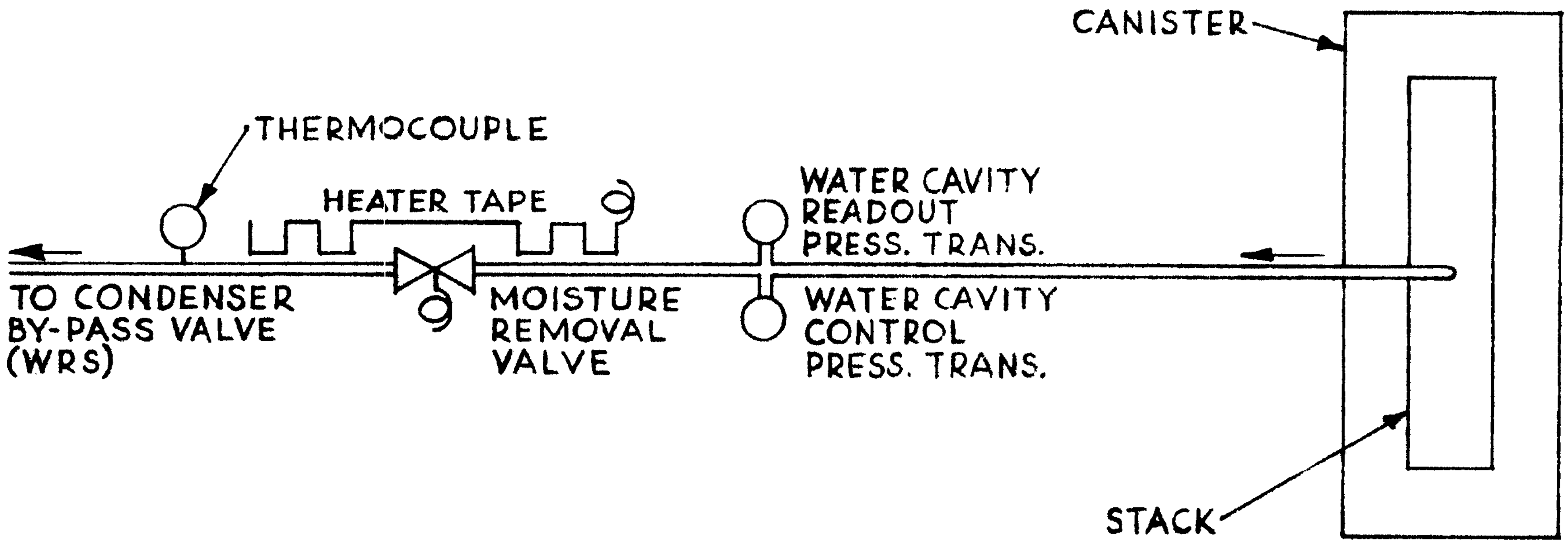


FIG. 4-6 MOISTURE REMOVAL SUBSYSTEM (MRS)

4.5 ELECTRICAL MONITORING AND CONTROL SUBSYSTEM (EMCS)

The EMCS consists of a power supply, a temperature controller, a purge controller, a moisture removal controller, and a master controller. These controllers are built-up on a number of printed circuit boards cards, and all are mounted in a single control box. The circuits for these various controllers have been designed to use static control throughout, with the exception of the output devices which are miniature-type latching relays. This arrangement permits isolation of the valve control solenoids from their electronic circuits. A brief functional desctiption of each of the controllers follows in the succeeding paragraphs.

4.5.1 Control Power Supply —

Figure 4-7 (Drawing No. 49-200-493-501),
Figure 4-8 (Drawing No. 49-300-542-401),
Figure 4-9 (Drawing No. 49-300-496-401),
Figure 4-10(Drawing No. 49-200-492-501),
Figure 4-11 (DrawingNo. 49-200-484-401),
Figure 4-12 (DrawingNo. 49-400-300-401),

The control power supply provides up to 10 watts of dc. power at the following voltages: +11.2 v $\pm$ 0.5% and -5.62 v $\pm$ 0.5%. These voltages are

CIRCUIT COMPONENT LIST FOR DRAWING 49-300-[illegible]-401 PIX

IT. NO.	REFERENCE DESIGNATION	NO. REQ.	DESCRIPTION	MIL SPEC. OR MFG. NAME AND CODE	MIL TYPE OR MFG. PART NO.
1		X	Bill of Material Mod. 10 Control Inverter (Regulator Board)		49-200-493-501
2	R1, 3, 4, 6, 26	5	Resistor, Fixed Film, 2.2K ± 5%, 0.25W.	Mil-R-22684	RL07AD222J
3	R7, 11, 13, 17, 18, 21, 22, 24, 25, 14, 28, 15,	12	Resistor, Fixed Film, 1K ± 5%, 0.25W.	Mil-R-22684	RL07AD102J
4	R9	1	Resistor, Fixed Film, 4.7K ± 5%, 0.25W.	Mil-R-22684	RL07AD472J
5	R32, 35, 34, 36	4	Resistor, Fixed Film, * ± 5%, 0.25W.	Mil-R-22684	RL07AD
6	R10, 12, 16	3	Resistor, Fixed Film, 3.3K ± 5%, 0.25W.	Mil-R-22684	RL07AD332J
7	R20, 23	2	Resistor, FIXED FILM, 22Ω ± 5%, 0.50W.	Mil-R-22684	RL20AD220J
8	R19, 30	2	Resistor, Fixed Film, 10K ± 5%, 0.25W.	Mil-R-22684	RL07AD103J
9	R29	1	Resistor, Fixed Film 2K ± 5%, 0.25W.	Mil-R-22684	RL07AD202J
10	R8,	1	Resistor, Fixed Film, 470Ω 5% .25W.	Mil-R-22684	RL07AD471J
11	C10	1	Capacitor, Tantalum Polar 330 uf, 6V.	Mil-C-26655B	CS13BB337K
12	C1, 2	2	Capacitor, MYLAR 0.022uf	CORNELL DUBILIER	WMF 1S22
13	C3	1	Capacitor, Tantalum Polar, 10mf, 35V	Mil-C-26655B	CS13BF106K

14	C4, 5	2	Capacitor, MYLAR 0.033 mfd	CORNELL DUBILIER	WMF1S33
15	C6	1	Capacitor, Tantalum 6.8uf 35V.	Mil-C-26655B	CS13BF685K
16	C7, 8	2	Capacitor, Ceramic 10000 pf		CK06CW103K
17					
18	CR1, 2, 5,	3	Diode	MSFC-338/3	S1N626
19	CR6	1	Zener Diode 11.2V.	MSFC-338/7	S1N3021B
20	CR7	1	Zener Diode 5.6 V.	MSFC-338/8	S1N752A
21	Q1, 2, 3, 4, 5, 6,	6	Transistor	MSFC-338/108	S2N1132
22	Q7, 8, 9,	3	Transistor	MSFC-388/105	S2N697
23	C11	1	Capacitor, Tantalum Polar 2.7uf 35V.	Mil-C-26655B	CS13BF275K
24	C13	1	Capacitor, Tantalum Polar 100uf 35V.	Mil-C-26655B	CS13BF107K
25	C12	1	Capacitor, Ceramic 4700pf		CK06CW472K
26	R27	1	Resistor, Fixed Film 470Ω ±5% 0.25W	Mil-R-22684	RL07AD471J
27	R2, R5	2	Resistor, Fixed Film 22K ±5% 0.25W	Mil-R-22684	RL07AD223J
28	P2007	1	CONNECTOR	WINCHESTER	SMRE-20-PGH
29	R33	1	RESISTOR, FIXED FILM 1.5K±5% 0.25W	MIL-R-22684	RL07AD152J
30		1	PRINTED CIRCUIT BOARD		49-300-593-001

31		9	PAD, TRANSISTOR MOUNTING	TRANSI PAD PRODUCTS	10012 DAT-BLACK
32		7	TERMINAL, TURRET	USECO	2030B
33		AR	WIRE AWG #26 TYPE B	MIL-W-16878D	ALPHA #7853
34		AR	SOLDER SN60	QQ-S-571	TYPE RA
35		AR	FLUX	MIL-F-14256	TYPE A
36		AR	CONDUCTOR, SOLID AWG #24	QQ-W-343	BELDEN 8022
37		AR	SHRINK TUBING RNF-100	MSFC-SPEC-276	276-11 TOD 05 DIA
REF.		—	ELECTRICAL SCHEMATIC		49-300-486-401
38		AR	LACING TAPE, BLACK	MIL-T-713A	ALPHA #LC134
			ASSY. USED ON: 49-200-585-501 & -502		* VALUES TO BE DETERMINED ON TEST

01 2-4-66

DELETED CAPACITORS C9 (IT.19) C14 & 15 (IT.12) CAPACITORS C4 & 5 (IT.14) WERE 0.01uf ADDED IT. 26

02 3-25-66

IT.11 WAS CS13BF337K
IT.12 WAS METALIZED PAPER, MIL-C-25, 118P1259252
IT.18 WAS SIN1626A
IT.24 WAS 100 uf CS13BF476K
IT.27 WAS RL, 1 Req'D, 18K, RL07AD183J
ADDED IT.29 THRU IT.38
TITLE WAS MOD 10 CONTROL INVERTER

UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES & MACHINING TOLERANCES ARE: | ANGLES ±

DIMENSIONS	UP TO 6 INCL	OVER 6 TO 24 INCL	OVER 24
FRACTIONAL	±	±	±
DECIMAL	±	±	±

— Confidential — Property of
ALLIS-CHALMERS MFG. CO., Milwaukee, Wis.

3341 DEPT.

DRN D. G. S. 1-27-66
TR'D
CHK'D 1-27
APPD

Bill of Material

REGULATOR CONTROLLER INVERTER MOD 10

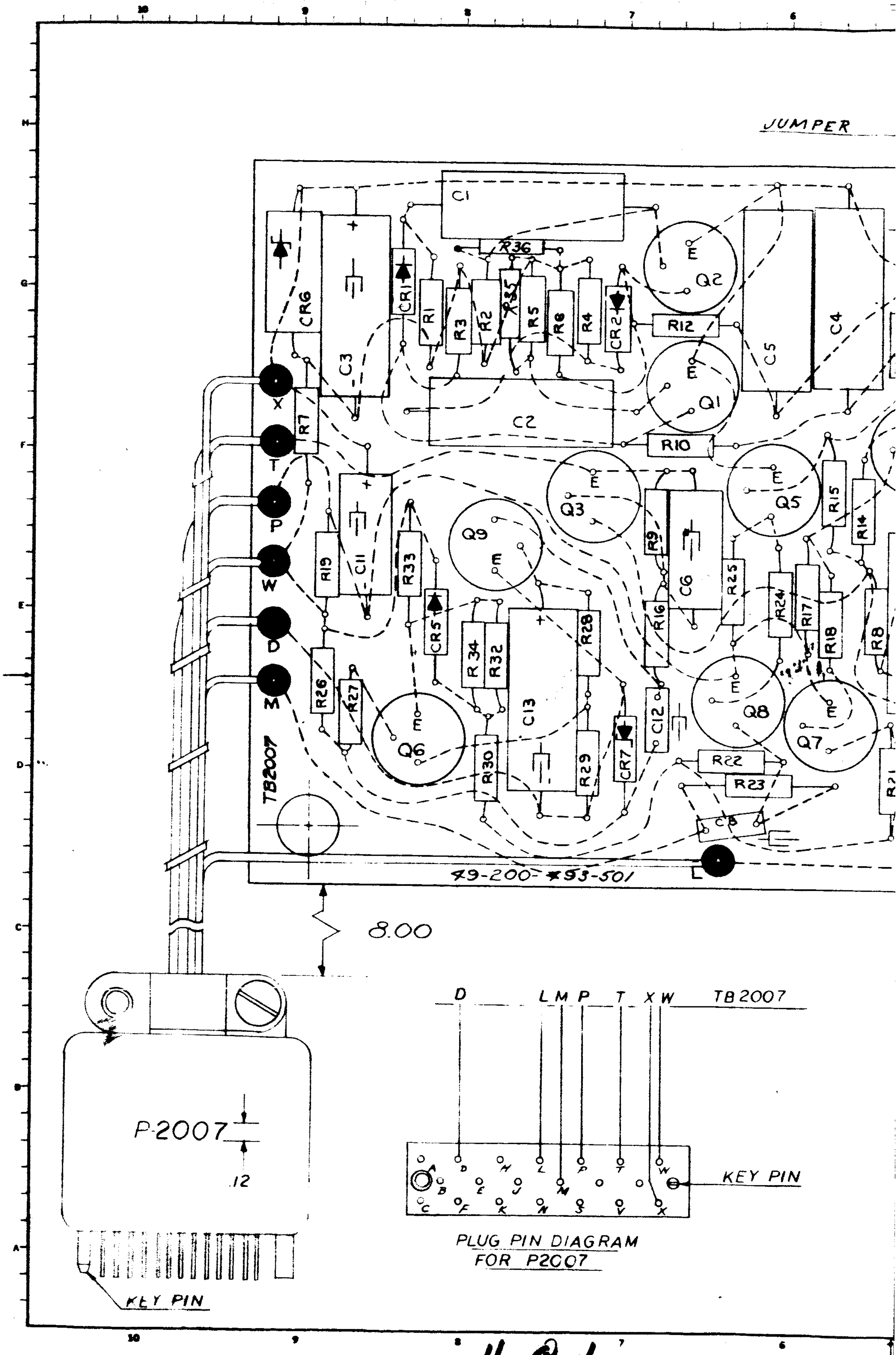
FIGURE 4-7

SIMILAR TO: SCALE

SHEET 1 OF 1

49-200-493-501

MILWAUKEE, WIS. FORM

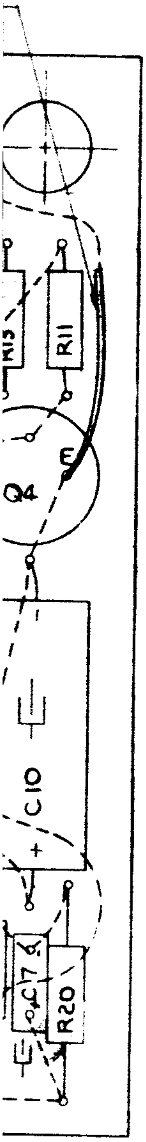


JUMPER
TB2007
49-200-*93-501
8.00
P-2007
.12
KEY PIN
D L M P T X W TB2007
KEY PIN
PLUG PIN DIAGRAM
FOR P2007

01	5-3-1966
REL. E.O. 0170	

NOTES:

1. PRINTED CIRCUIT ASSEMBLY TO BE CONSTRUCTED AND INSPECTED PER NPC 200-4
2. ALL TERMINALS SHALL BE MOUNTED ON THE PRINTED CIRCUIT BOARD PRIOR TO INSERTING ELECTRICAL COMPONENTS
3. TERMINAL IDENTIFICATION, PART, & PLUG NUMBERS ARE TO BE APPLIED IN BLACK INK .12 INCH HIGH IN POSITION SHOWN
4. COAT ALL TERMINAL IDENTIFICATION, PART, & PLUG NUMBERS WITH CLEAR LACQUER
5. AFTER QUALITY CONTROL HAS TESTED AND ACCEPTED THE PRINTED CIRCUIT ASSEMBLY APPLY A CONFORMAL COATING TO BOTH SIDES OF BOARD COATING MUST COMPLY WITH MSFC-PROC-257
6. REFERENCE DWG.
   - PRINTED CIRCUIT BOARD 49-300-543-001
   - PRINTED CIRCUIT MASTER 49-300-543-091
   - ELECTRICAL SCHEMATIC 49-200-486-401



49-300-542-401 ISSUE 01

49-200-493-501

NEXT ASSEMBLY USED ON

CONFIDENTIAL — PROPERTY OF
ALLIS-CHALMERS MFG. CO.
3341 MI WORKS

NAME: PRINTED CIRCUIT ASSEMBLY CONTROL INVERTER

UNLESS OTHERWISE SPECIFIED:
1 - PLACE DEC ±
2 - PLACE DEC ± .01
3 - PLACE DEC ±
ANGULAR ±

MACHINED SURFACE TEXTURE

MATL

FIGURE 4-8

WT R F

SIMILAR TO

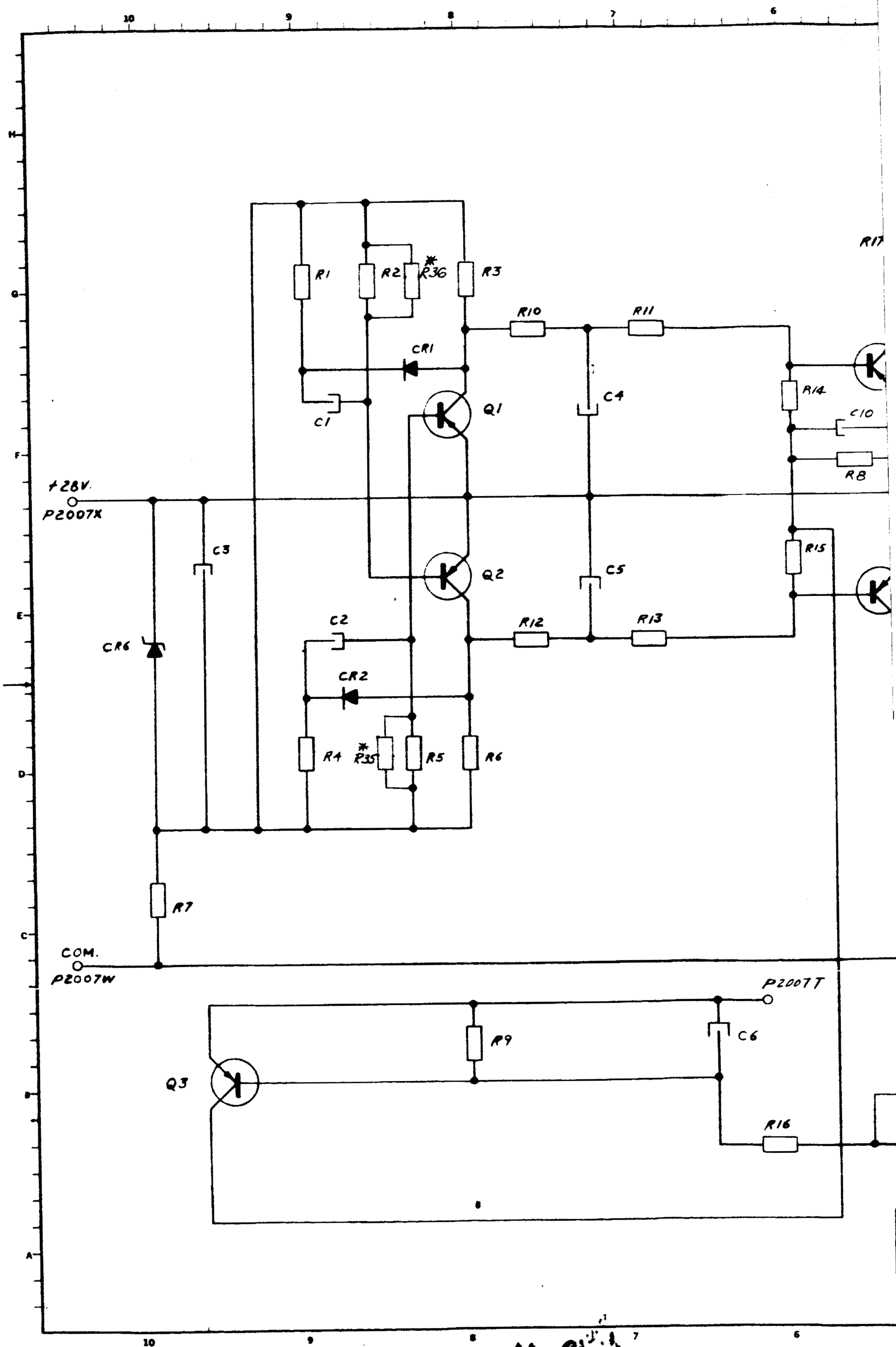
DR JJL (UDC)
CH J.M. 5/3/66
AP

SCALE 3:1 SHEET FINAL

PART NO 49-300-542-401

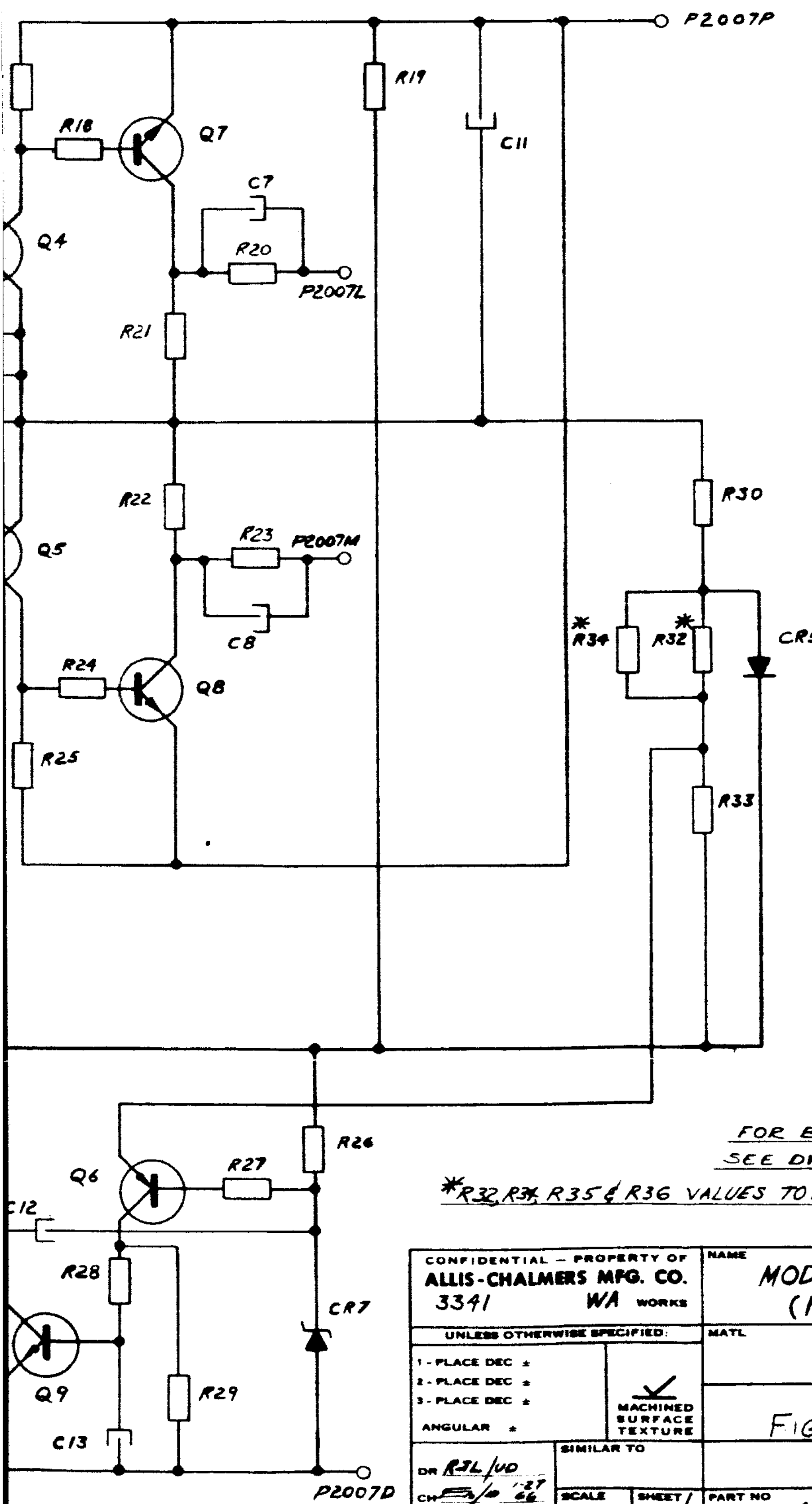
#1058 (UDC)

PRINTED IN U.S.A. FORM No. 8132-1



R1
R2
R36
R3
R10
R11
R17
CR1
C4
Q1
R14
C10
C1
R8
+28V.
P2007X
C3
Q2
C5
R15
C2
R12
R13
CR6
CR2
R4
R35
R5
R6
R7
COM.
P2007W
P2007T
R9
C6
Q3
R16

01	2-4-66	JB.
DELETED CAPACITORS C9, C14 & C15		
02	3-25-66	
SEE 3/26/66 REL E.O. 0150		
ADDED R35 & R36		
03	5-2-1966	
E.O. 0170		



FOR BILL OF MATERIAL SEE DWG. 49-200-493-501

*R32, R34, R35 & R36 VALUES TO BE SELECTED DURING TEST

CONFIDENTIAL – PROPERTY OF ALLIS-CHALMERS MFG. CO. 3341 WA WORKS

NAME: MOD. 10 CONTROL INVERTER (REGULATOR)

UNLESS OTHERWISE SPECIFIED: 1-PLACE DEC ± 2-PLACE DEC ± 3-PLACE DEC ± ANGULAR ±

MACHINED SURFACE TEXTURE

MATL

FIGURE 4-9

WT R F

SIMILAR TO

DR RJL/UD CH 1-27-66 AP 2/5/66

SCALE —

SHEET / OF 1

PART NO 49-300-486-401

ISSUE 03 — 49-300-486-401

PRINTED IN U.S.A. FORM No 8122-1

CIRCUIT COMPONENT LIST FOR DRAWING 49-300-503-401

IT. NO.	REFERENCE DESIGNATION	NO. REQ.	DESCRIPTION	MIL SPEC. OR MFG. NAME AND CODE	MIL TYPE OR MFG. PART NO.
1		1	Circuit Board		49-300-501-001
2		22	Terminal-Feed Thru	USECO	2500C -1
3		23	Terminal	USECO	2030C -1
4	CR1,2,4,5,6,7, 8,9,10,11,12,13 14,15	14	Diode		IN4003
5	CR3	1	Zener Diode 75V.		IN3041B
6	T-1	1	Transformer		49-200-491-401
7	T-2	1	Input Choke		49-200-489-401
8	T-3	1	Output Choke		49-200-490-401
9	C1	1	Capacitor, Tantalex 110uf 50V.		130D117C2050W2
10	C2	1	Capacitor, Tantalum Polar 100mf 15V	MIL-C-26655A	CS13AE101K
11	C4	1	Capacitor, Tantalex 350mf 15V.		130D357C2015W2
12		4	Washer-0.75 O.D.x0.125 I.D.x.093 Thk.	Make From Glass Epoxy	49-200-492-012
13		2	Washer-0.50 O.D.x0.125 I.D.x.093Thk.	Make From Glass Epoxy	49-200-492-013
14		2	No.6-32x1.25 Lg. Mach. Screw		49-200-492-014
15		1	No.6-32x1.00 Lg. Mach. Screw		00-6[illegible]-2[illegible]-132

4-10-1

16		6	No. 6 Rd. Washer		00-651-027-050
17		3	No. 6 Lockwasher		00-655-017-018
18		3	No. 6-32 Hex. Nut		00-631-123-106
19		2'8"	#22 AWGTFE Teflon Insul. Stranded Silver Plated Copper Type E - White	MIL-W-16878D	Alpha 2855 or Equivalent
20		YES	WIRING SCHEMATIC		49-200-484-401

9-10-2

49-200-531-502	
49-200-531-501	
NEXT ASSEMBLY	USED ON

01	2-4-66
Revised & Retyped	
02	3-2-66

UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES & MACHINING TOLERANCES ARE

DIMENSIONS	UP TO 6 INCL.	OVER 6 TO 24 INCL.	OVER 24
FRACTIONAL	±	±	±
DECIMAL	±	±	±

ANGLES ±

— Confidential — Property of

ALLIS-CHALMERS MFG. CO., Milwaukee, Wis.

RESEARCH #3341

DEPT.

DR'N	RAR 2-18-66	CH'D	2-28-66
TR'D		APP'D	3-19-66

BILL OF MATERIAL

CONTROLLER INVERTER
OUTPUT BOARD
MOD. 10

FIGURE 4-10

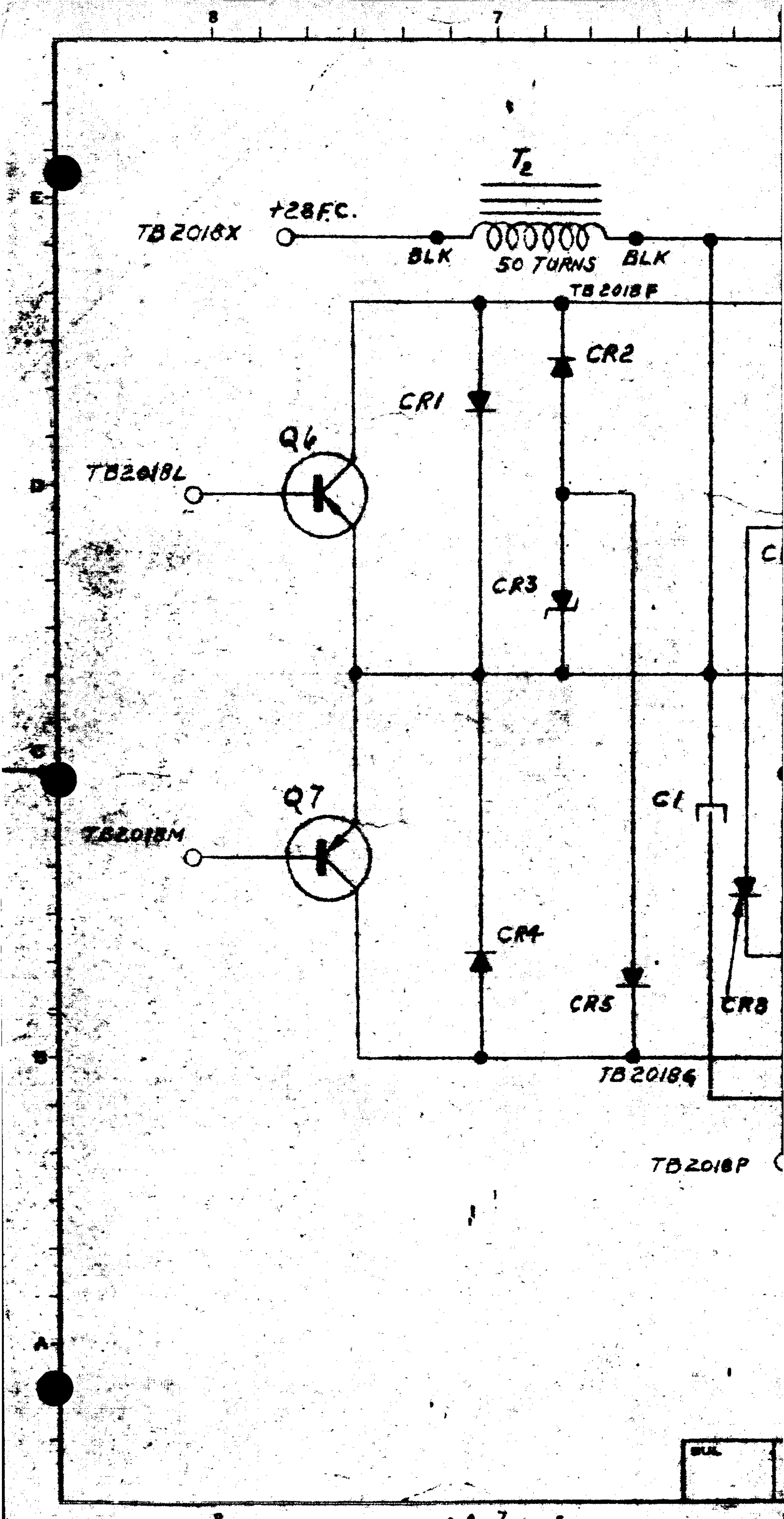
SIMILAR TO

SCALE

SHEET OF

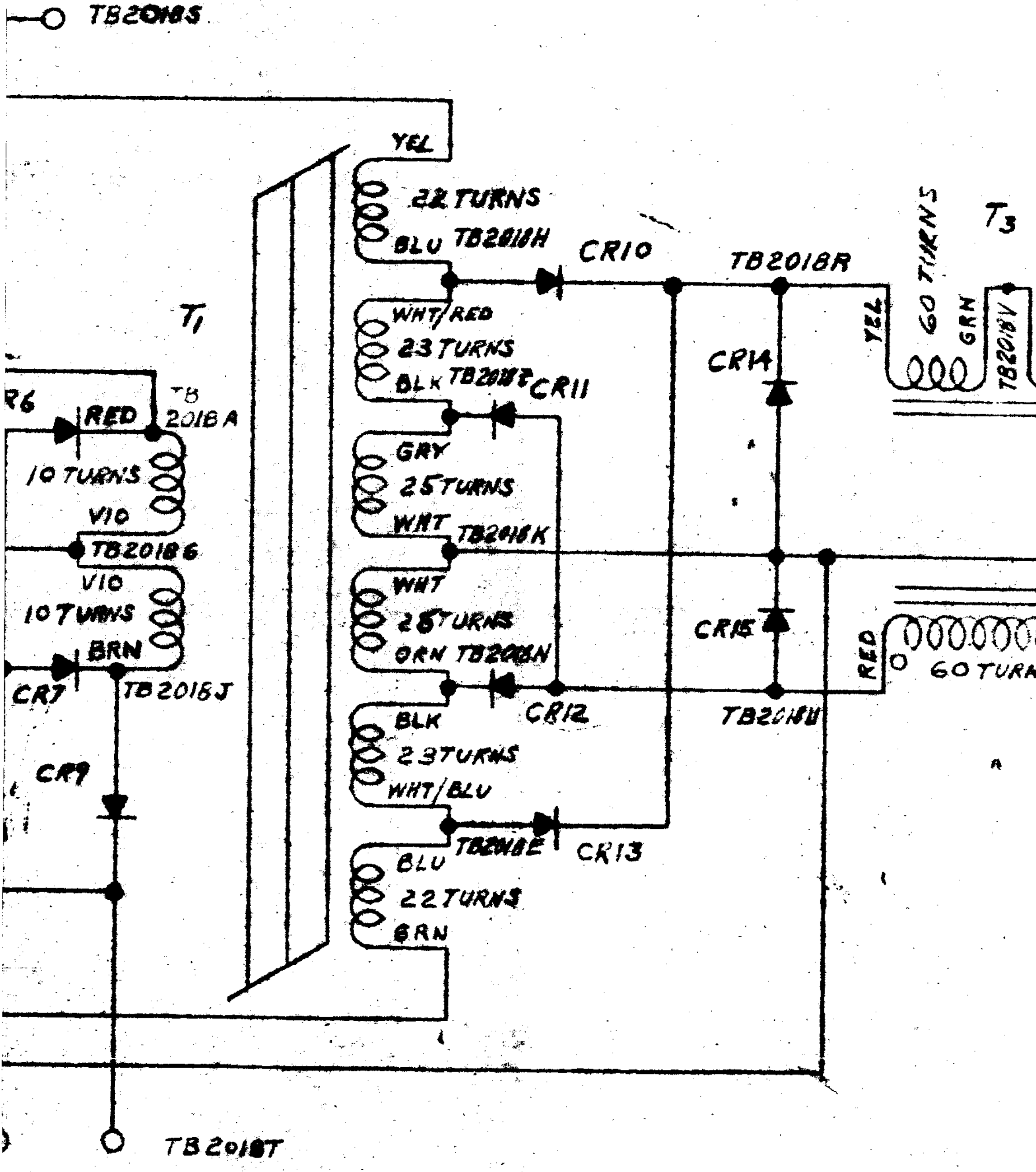
49-200-492-501

4-10-3



T2
TB2018X
+28F.C.
BLK
50 TURNS
BLK
TB2018F
CR2
CR1
Q6
TB2018L
CR3
Q7
TB2018M
C1
CR4
CR5
CR8
TB2018G
TB2018P

4-111

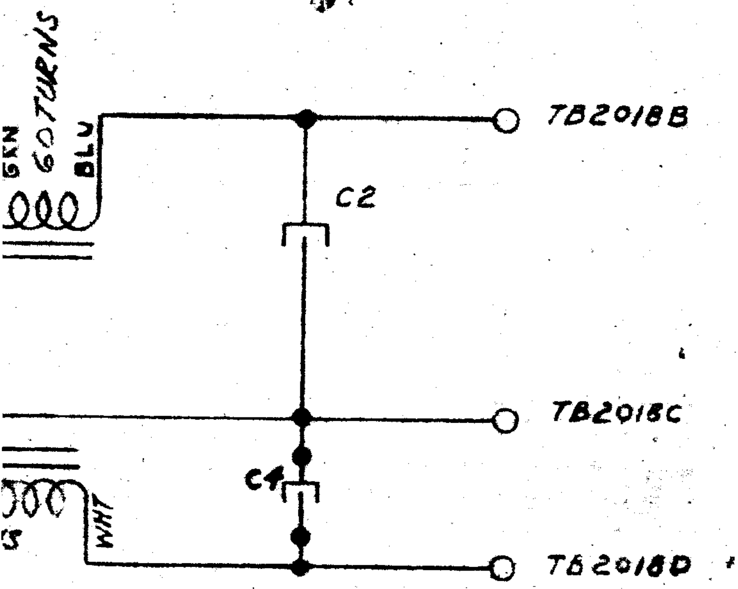


CON
ALLI
33
UNLE
1-PLACE
2-PLACE
3-PLACE
ANGULA
DR
CK
AP

49-200-484

ISSUE 02

01	2-4-66
NUMBER OF TURNS REVISED	
02	2-25-66



FOR BILL OF MATERIAL SEE
DWG. 49-200-492-501

FIDENTIAL—PROPERTY OF
S-CHALMERS MFG. CO.
41 WA PLANT

SS OTHERWISE SPECIFIED:
DEC ±
DEC ±
DEC ±
AR ±

MACHINED SURFACE TEXTURE

SIMILAR TO

SCALE | SHEET

NAME
MOD. 10 CONTROL INVERTER
(POWER OUTPUT)

MATL.

FIGURE 4-11

WT R F

PART NO.
49-200-484-401

PRINTED IN U.S.A. FORM NO. 6131-1

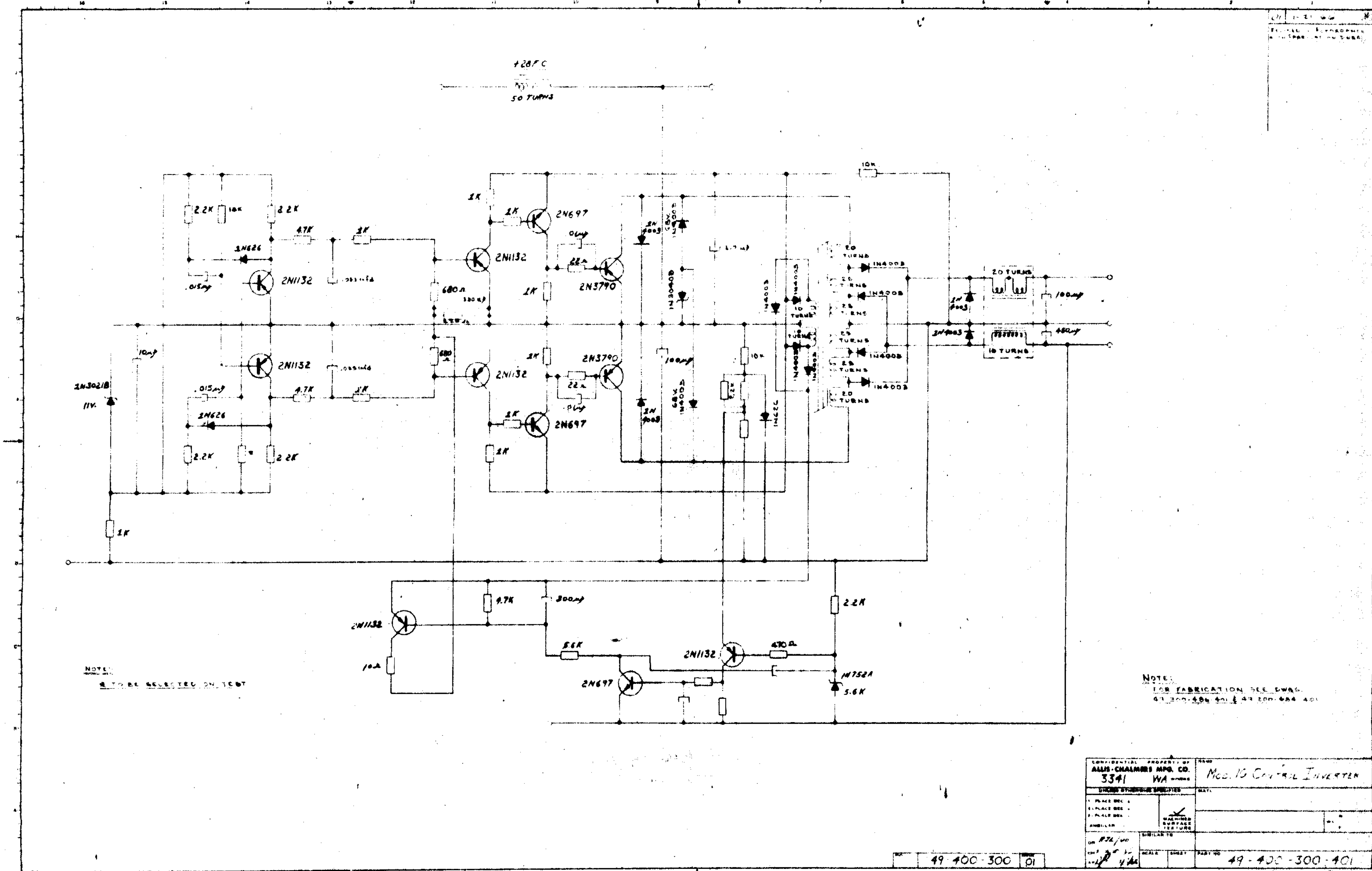

+28 F C
50 TURNS
2.2K
10K
2.2K
1N626
4.7K
1K
2N1132
.015mf
680Ω
2N697
2N1132
2N3790
20 TURNS
1N4003
100mf
450mf
10 TURNS
1N3021B
11V.
2N3790
2N697
2.2K
1N752A
5.6K
2N1132
470Ω
4.7K
300mf
5.6K
10Ω
2N697
NOTES:
* TO BE SELECTED ON TEST
NOTES:
FOR FABRICATION SEE DWGS.
ALLIS-CHALMERS MFG. CO.
3341
WA
MOD. 10 CONTROL INVERTER
49-400-300
01
49-400-300-401

FIGURE 4-12

supplied by a dc. to dc. inverter from the auxiliary 28 volts dc. power source which may be either the fuel cell output or an external source. The control power supply is designed to operate over an input voltage of 18 to 35 vdc with an overall efficiency of not less than 70% at a 28 volt input. The power supply operates as follows. The output of an 800 cycle, free running, square wave oscillator, is modified to a triangular wave. The triangular wave drives an amplifier into saturation over approximately 165 electrical degrees. The output of this amplifier drives a transformer which operates similar to an AUTO transformer being alternately switched across the dc. power source. One secondary winding provides power for the 11.2 vdc filter network. Another secondary winding provides the power for the -5.6 vdc filter network, which in turn feeds the main voltage regulator circuit. A reactor forms part of the filtering network of both the +11.2 and the -5.6 vdc outputs. It acts as a load equalizer for any unbalanced load currents between these two outputs. The main voltage regulator circuit controls the bias applied to amplifier, thereby providing pulse width voltage regulation.

4.5.2 Temperature Controller See Figure 4-13A and 14-13B (Dwg. No. 49-200-413-501), Fig. 4-14 (Dwg. No. 49-400-337-401), Fig. No. 4-15 (Dwg. No. 49-400-293-401).

The temperature controller consists of 3 distinct circuits: the sensing circuit, the coolant circuit, and the heating circuit. The sensing circuit determines whether cooling or heating is required by sensing the fuel cell stack temperature. It then provides a signal to either the coolant control circuit or the heating circuit, which control respectively, the liquid coolant control valve or the fuel cell stack standby heaters.

The temperature of the fuel cell stack is monitored by a thermistor located on the stack. This signal is fed to an operational amplifier whose output is

CIRCUIT COMPONENT LIST FOR DRAWING 49-400-337-401 YX

IT. NO.	REFERENCE DESIGNATION	NO. REQ.	DESCRIPTION	MIL SPEC. OR MFG. NAME AND CODE	MIL TYPE OR MFG. PART NO.
1	R34, 36 R1, 2, 9, 23,	6	Resistor Fixed Film, 2.2K ± 5% 0.25W	MIL-R-22684	RL07AD222J
2	R3, 11, 55	3	Resistor Fixed Film, 5.6K ± 5% 0.25W	MIL-R-22684	RL07AD562J
3	R4, [illegible], 16, 17, 12, 28, 33, 37, 44, 43	9	Resistor Fixed Film, 10K ± 5% 0.25W	MIL-R-22684	RL07AD103J
4	R5, 26	2	Resistor Fixed Film, 1.8K ± 5% 0.25W	MIL-R-22684	RL07AD182J
5	R6, 27	2	Resistor Fixed Film, 220 ohms ± 5% 0.25W	MIL-R-22684	RL07AD221J
6	R7, 29, 32, 35	4	Resistor Fixed Film 100K ± 5% 0.25W	MIL-R-22684	RL07AD104J
7	R8, 24	2	Resistor Fixed Film 8.2K ± 5% 0.25W	MIL-R-22684	RL07AD822J
8	R10, 25	2	Resistor Fixed Film 6.2K ± 5% 0.25W	MIL-R-22684	RL07AD622J
9	R30, 22, 53, 51	4	Resistor Fixed Film 2K ± 5% 0.25W	MIL-R-22684	RL07AD202J
10	R31, 18, 21, 54, 42	5	Resistor Fixed Film 1K ± 5% 0.25W	MIL-R-22684	RL07AD102J
11	R45	1	Resistor Fixed Film 4.7K ± 5% 0.25W	MIL-R-22684	RL07AD472J
12	R15, 52	2	Resistor Fixed Film 3.3K ± 5% 0.25W	MIL-R-22684	RL07AD332J

1	R41	1	Resistor Fixed Film 5.1K $\pm$ 5% 0.25W	MIL-R-22684	RL07AD512J
14	R40	1	Resistor Fixed Film 20K $\pm$ 5% 0.25W	MIL-R-22684	RL07AD203J
15	R38, 14	2	Resistor Fixed Film 12K $\pm$ 5% 0.25W	MIL-R-22684	RL07AD123J
16	K1	1	Relay Permanent Magnet 24VDC	P & B	SC11DB
17	C2	1	Capacitor Ceramic 2200pf	MIL-C-11015C	CK06CW222K
18	C4, 5	2	Capacitor-Ceramic 470pf	MIL-C-11015C	CK05CW471K
19	C6	1	Capacitor Ceramic 1000pf 200V	MIL-C-11015C	CK05CW102K
20	C1, 3	2	Capacitor Tantalum Polar 10mf 35V	MIL-C-26655	CS13AF100K
21	C7, 10	2	Capacitor Tantalum Polar 47mf 35V	MIL-C-26655	CS13AF470K
22	CR1	1	Diode Zener 39V		IN3034B
23	CR3,	1	Diode	MSFC-338/3	SIN626
24	CR6	1	Diode		IN4003
25	CR5	1	Diode Zener 3.6V	MSFC-338/8	SIN747A
26	CR8	1	Diode Zener 6.8V	MSFC-338/8	SIN754A
27	Q1	1	Operational Amplifier	Fairchild	MA702A

28	12, 13, 17, 18	10	Transistor	MSFC-338/105	S2N697
29	Q3, 9, 10, 14	4	Transistor	MSFC-338/108	S2N1132
30	R19*, R13*	2	RESISTOR FIXED FILM * ± 5% 0.25W	MIL-R-22684	*
			*VALUE SELECTED DURING TEST		
32	R20	1	RESISTOR FIXED FILM 6.8K ± 5% 0.25 W	MIL-R-22684	RL07AD 682J
33	R50	1	RESISTOR FIXED FILM 470Ω ± 5% 0.25W	MIL-R-22684	RL07AD 471J
34	C8	1	CAPACITOR CERAMIC 1500 pf	MIL-C-11015C	CK06CW152K
35	C11	1	CAPACITOR CERAMIC 6800 pf	MIL-C-11015C	CK06CW682K
36	C9	1	CAPACITOR TANTALUM 27mf 35V.	MIL-C-26655	CS13AF270K
37	Q19	1	TRANSISTOR	MSFC-338/119	S2N1486
38	CR10	1	DIODE ZENER		IN3034B
39	P2011	1	CONNECTOR	WINCHESTER	SMRE-20-PGH

01 9-14-65
RETYPED
02 2-7-66
R34,36 WERE 1K (IT.10)
R12 WAS 10K (IT.8)
R14,20 WERE 12K (IT.15)
R42 WAS 2K (IT.9)
R19 WAS 4.7K (IT.11)
ADDED R50 (IT.33), R51 (IT.1), R52 (IT.12), R53 (IT.9) & R54 (IT.10) & Q18 (IT.28)
ADDED ITEMS 34, 35, 36, 37 & 38
IT.19 WAS 1000 pf

CK06CW103K ADDED IT. 39
03 3-25-66
EPE 3/26/66
REL. EO. 0150
IT.1-DELETED R51 & 45 WAS (8) REQ'D.
IT.2-DELETED R45 ADDED R55.
IT.3-DELETED R21 ADDED R43
IT.9 ADDED R51 WAS (3) REQ'D.
IT.23 DELETED CR9 WAS (2) REQ'D.
IT.25 DELETED CR2 & 4 WAS (3) REQ'D.
IT.28 ADDED Q8 WAS 9 REQ'D. (CONT'D ON SH 2)
04 5-18-66 EO190

UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES & MACHINING TOLERANCES ARE:

ANGLES ±

DIMENSIONS	UP TO 6 INCL.	OVER 6 TO 24 INCL.	OVER 24
FRACTIONAL	±	±	±
DECIMAL	±	±	±

[redacted] – Property of
ALLIS-CHALMERS MFG. CO., Milwaukee, Wis.

RESEARCH #3341 DEPT.

DR'N R. LL. 2/7/66
CH'D 5/4/66
TR'D
APP'D 2/ /66

TEMPERATURE CONTROLLER MOD. 10

FIGURE 4-13A

SIMILAR TO:
SCALE
SHEET 1 OF 2.
49-200-413-501

4-13A-3

REQ.	ITEM	DESCRIPTION	MIL. SPEC. OR MFG. ~~MATERIAL~~	PART NUMBER
14	40	Pad, Transistor Mounting	Transipad Products	100-12DAT-Black
1	41	Pad, Transistor Dual	Milton Ross	10229
23	42	Terminal Turret	USECO	2030B
AR	43	Wire AWG #26 Type B	MIL-W-16878/1	Alpha #1853
AR	44	Conductor, Solid AWG #24	QQ-W-343	Belden #8022
AR	45	Shrink Tubing RNF-100	MSFC-SPEC-276	276-11TOD05 DIA
AR	46	Solder SN60	QQ-S-571	Type RA
AR	47	Flux	MIL-F-14256	Type A
1	48	Printed Circuit Board		49-400-338-001
6	49	Screw	MS-51957	MS51959-14
6	50	Nut, Self Locking	NAS1021	NAS1021C04
6	51	Washer, Plain	MS-15795	MS15795-804
AR	52.	LACING TAPE, BLACK	MIL-T-713A	ALPHA #LC134

ASSEMBLY USED ON 49-200-585-501
49-200-585-502

	Ref.	Electrical Schematic		49-400-293-401

CONT'D FROM SH. #1
ADDED SH. #2 ELT'S

04 5-4-66

E.O. 01[illegible]

— PROPERTY OF
ALLIS-CHALMERS MFG. CO.
Research 3341 PLANT

NAME: Temperature Controller MOD. 10

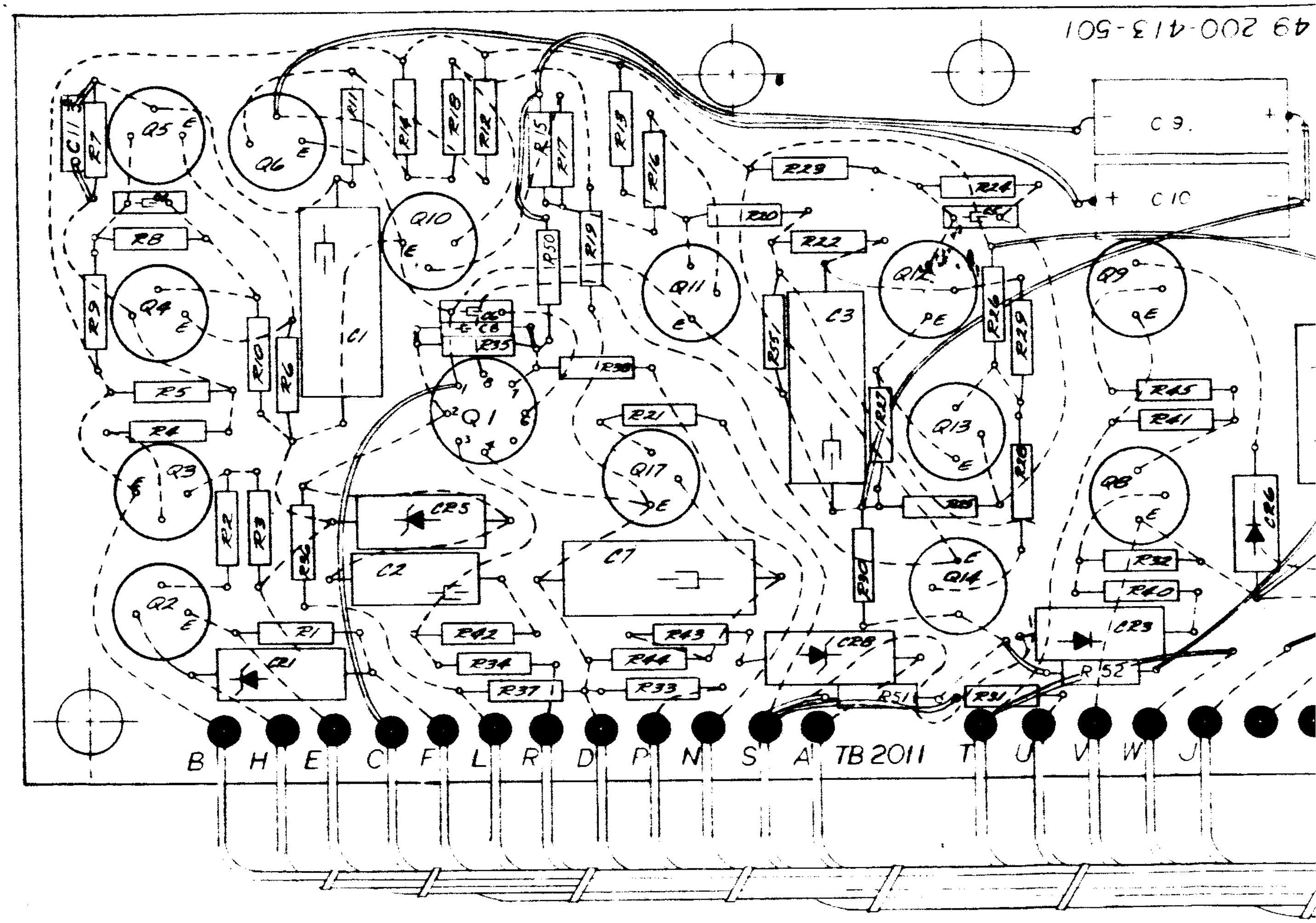
SIMILAR TO

DR
CH EJK
AP

FIGURE 4-13B

SCALE NA
SHEET 2 of 2
PART NO 49-200-413-501

U-13-B



C11
R7
Q5
Q6
R11
R14
R18
R12
R15
R17
R13
R16
C9
C10
R29
R24
R20
R22
R8
Q10
Q11
Q12
Q9
R9
Q4
R10
R6
C1
C6
R35
R50
R19
C3
R51
R26
R29
R5
R4
Q1
R38
R21
Q13
R27
R45
R41
Q3
R2
R3
R36
CR5
Q17
R30
Q8
CR6
C2
C7
Q14
R32
R40
Q2
R1
R42
R43
CR8
CR3
CR1
R34
R44
R37
R33
R51
R31
R 52
B
H
E
C
F
L
R
D
P
N
S
A
TB 2011
T
U
V
W
J

4-14-1

01 5-3-1966

REL E.O. 0190

NOTES:

1. PRINTED CIRCUIT ASSEMBLY TO BE CONSTRUCTED & INSPECTED PER NPC 200-4

2. ALL TERMINALS SHALL BE MOUNTED ON THE PRINTED CIRCUIT BOARD PRIOR TO INSERTING ELECTRICAL COMPONENTS

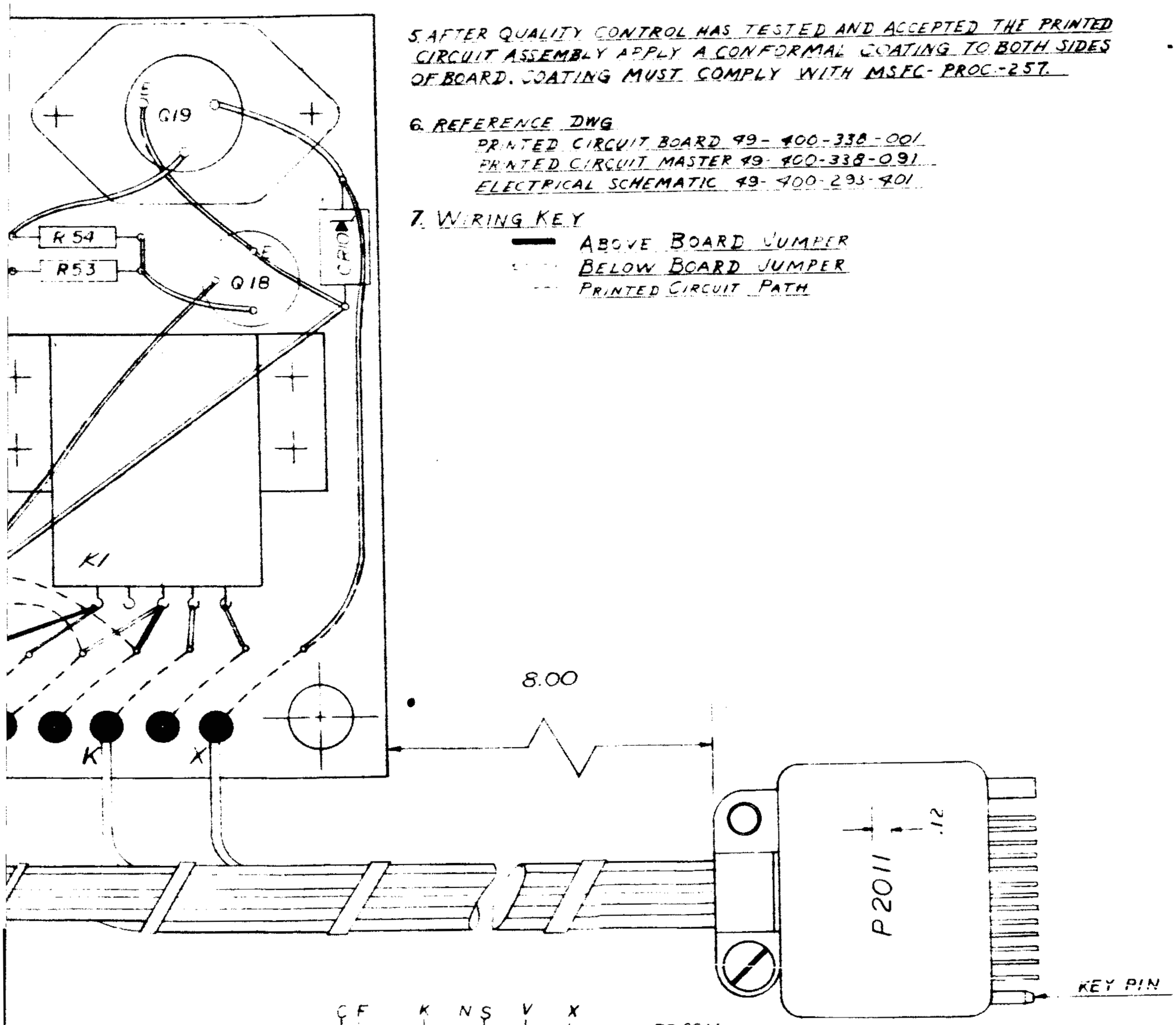
3. TERMINAL IDENTIFICATION, PART & PLUG NUMBERS ARE TO BE APPLIED IN BLACK INK .12 INCH HIGH IN POSITION SHOWN

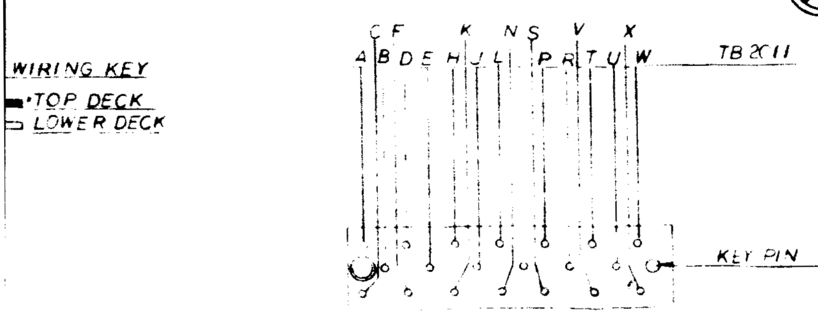
4. COAT ALL TERMINAL IDENTIFICATION, PART & PLUG NUMBERS WITH CLEAR LACQUER

5. AFTER QUALITY CONTROL HAS TESTED AND ACCEPTED THE PRINTED CIRCUIT ASSEMBLY APPLY A CONFORMAL COATING TO BOTH SIDES OF BOARD. COATING MUST COMPLY WITH MSFC-PROC-257.

6. REFERENCE DWG
   PRINTED CIRCUIT BOARD 49-400-338-001
   PRINTED CIRCUIT MASTER 49-400-338-091
   ELECTRICAL SCHEMATIC 49-400-293-401

7. WIRING KEY
   ABOVE BOARD JUMPER
   BELOW BOARD JUMPER
   PRINTED CIRCUIT PATH





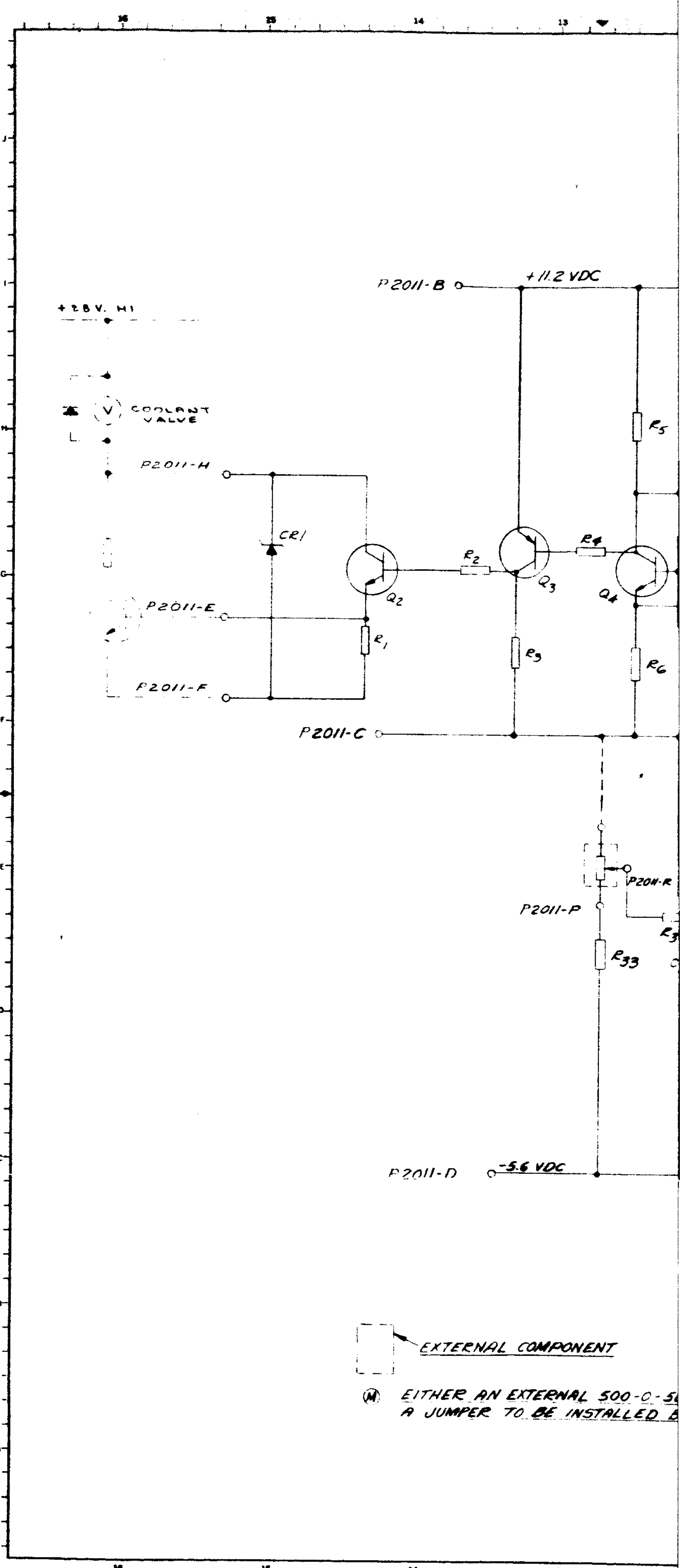
PLUG PIN DIAGRAM FOR P2011

	49-200-413-501
	NEXT ASSEMBLY USED ON
CONFIDENTIAL—PROPERTY OF ALLIS-CHALMERS MFG. CO. PLANT	NAME: PRINTED CIRCUIT ASSEMBLY TEMPERATURE CONTROLLER II
UNLESS OTHERWISE SPECIFIED: 1-PLACE DEC ± 2-PLACE DEC ± .01 3-PLACE DEC ± ANGULAR ± ; MACHINED SURFACE TEXTURE √	MATL
	FIGURE 4-14
DR 3-24-66 CH 5/3/66 AP	SIMILAR TO
SCALE · SHEET	PART NO. 49-4[illegible]

4-400-3[illegible] ISSUE 01

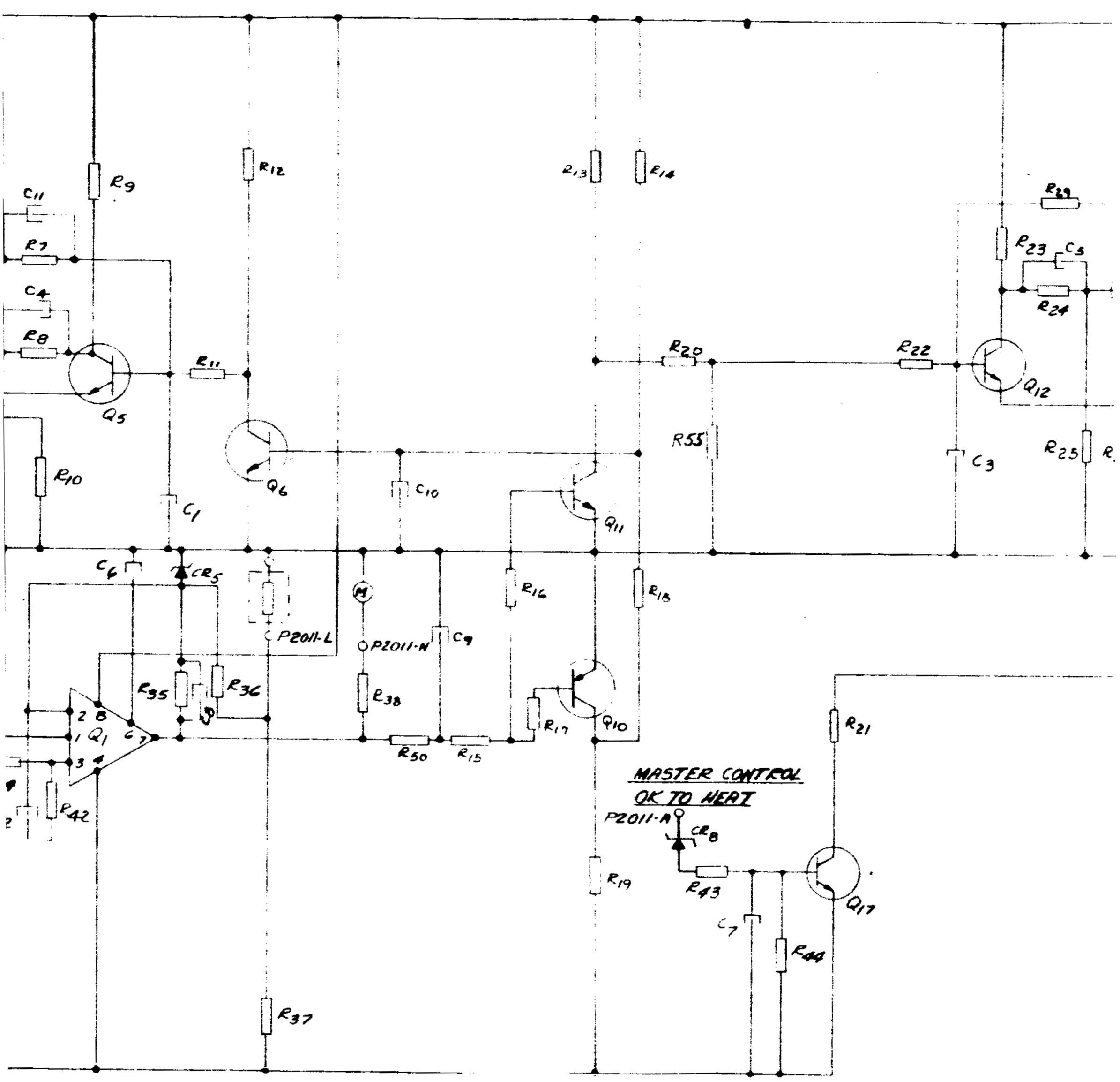
PRINTED IN U.S.A.

J. 10-2



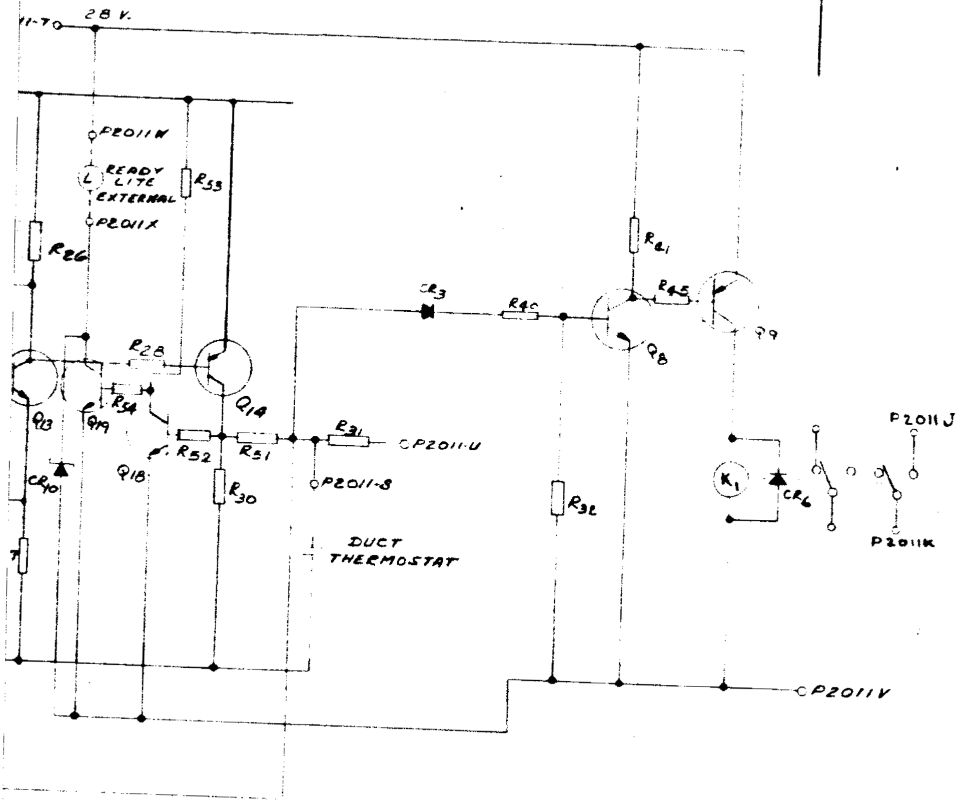
+28V. HI
COOLANT VALVE
P2011-B
+11.2 VDC
P2011-H
CR1
P2011-E
P2011-F
P2011-C
R_5
R_4
R_2
Q_2
Q_3
Q_4
R_1
R_3
R_6
P2011-R
P2011-P
R_{33}
P2011-D
-5.6 VDC
EXTERNAL COMPONENT
(M) EITHER AN EXTERNAL 500-0-5
A JUMPER TO BE INSTALLED

4-15-1



NOTE
FC
SE

0 μ AMP. METER OR
ETWEEN TERMINAL "N" & GROUND



01	2-7-66	
DWG REVISED & BROUGHT UP TO DATE		
02	3-25-66	
P2011J was P2011L		
03	4-21-66	

FOR BILL OF MATERIALS SEE DWG. 49-200-413-501

CONFIDENTIAL - PROPERTY OF ALLIS-CHALMERS MFG. CO. RSCH. #3341 M.I. WORKS

NAME: TEMPERATURE CONTROLLER II

UNLESS OTHERWISE SPECIFIED
1-PLACE DEC ±
2-PLACE DEC ±
3-PLACE DEC ±
ANGULAR ±

MACHINED SURFACE TEXTURE

MATL

FIGURE 4-15

WT

DR 12-29-65

SIMILAR TO

SCALE N.A. | SHEET 1 OF 1

PART NO 49-400-293-401

49-400-293-401 | ISSUE 03

PRINTED IN U.S.A.

a negative signal if cooling is required, or a positive signal if heating is required. The positive signal from the operational amplifier is fed to an inhibited AND gate. To satisfy the inhibited AND gate, the "OK to Heat Signal" from the master controller must be present, the "Stand by heater thermostat signal" cannot be present. Completing the input requirements of this gate, the output feeds a Schmitt trigger with dual outputs: one turns on the 100-watt current driver (100 watt supply for the standby heaters), the second output is the command signal for the 1,600 watt warm-up heaters. The negative signal from the operational amplifier feeds the coolant Schmitt trigger circuit which in turn triggers the relay driver for the coolant control valve.

4.5.3 Purge Controller - See Figure 4-16A and 4-16B (Dwg. No. 49-200-465-501), Fig. 4-17 (Dwg. No. 49-500-183-401), Fig. 4-18 (Dwg. No. 49-400-291-401).

Purging is accomplished by a brief and accurately timed opening of the purge valves which permit a rapid movement of hydrogen and oxygen through the respective reactant cavities of the fuel cell. This action cleans the cavities of inert gases which are an accumulation of impurities contained in the reactant gases. It is therefore evident that the frequencies of purging are related to the amount of reactant gases used and the amount of impurities in the gases. The amount of reactant gases used is directly related to the ampere-hours of current produced by the fuel cell.

The purge controller provides three modes of purging.

CIRCUIT COMPONENT LIST FOR DRAWING 49-500/183-401 P/A

IT. NO.	REFERENCE DESIGNATION	NO. REQ.	DESCRIPTION	MIL SPEC. OR MFG. NAME AND CODE	MIL TYPE OR MFG. PART NO.
1	R1	1	Resistor Fixed Film 51Ω ±5% 0.25W	MIL-R-22684/1	RL07AD510J
2	R2, 3, 141,6	4	Resistor Fixed Film 2.2K±5% 0.25W	MIL-R-22684/1	RL07AD222J
3	R5	1	Resistor Fixed Film 82K±5% 0.25W	MIL-R-22684/1	RL07AD823J
4	R10, 140,121	3	Resistor Fixed Film 1K±5% 0.25W	MIL-R-22684/1	RL07AD102J
5	R8, 14	2	Resistor Fixed Film 12K±5% 0.25W	MIL-R-22684/1	RL07AD123J
6	R11	1	Resistor Fixed Film 100Ω ±5% 0.25W	MIL-R-22684/1	RL07AD1[illegible]J
7	R12,13,15, 17,18,21,22, 25,26,[illegible],26, 33,34,38,144 40,41,45,145, 47,48,52,53,	60	Resistor Fixed Film 10K±5% 0.25W	MIL-R-22684/1	RL07AD10[illegible]J

4-16 R-1

	5[illegible],5[illegible],59,[illegible]3,[illegible]4, 6[illegible],67,71,73,74, 7[illegible],7[illegible],[illegible],82,8[illegible], 87,8[illegible],90,91,95, 9[illegible],9[illegible],99,103, 104,106,107,111, 112,115,116,118, 120,125,132,133, 138.				
8	R142,143,1[illegible],57, ,124,1[illegible],1[illegible], 128,129,13[illegible],13[illegible]	11	Resistor Fixed Film 4.7K±5% 0.25W	MIL-R-22684/1	RL07AD472J
9	R130.	1	Resistor Fixed Film 470Ω ±5% 0.25W	MIL-R-22684/1	RL07AD471J
10		1	PRINTED CIRCUIT BOARD		49-400-340-001
11	R19,24,21,38, [illegible] 54,55,[illegible],65,[illegible]9 72,77,[illegible],85,[illegible] 93,97,10[illegible],105 109,11[illegible],114,146 122,137.	29	Resistor Fixed Film 22K±5% 0.25W	MIL-R-22684/1	RL07AD223J
12	R122	1	Resistor Fixed Film 3.3K±5% 0.25 W	MIL-R-22684/1	RL07AD 332J
13	R4, [illegible], 136, 147, 148	5	Resistor Fixed Film *±5% 0.25W	MIL-R-22684/1	
14	C1,58,59.	3	Capacitor Ceramic 1000 pf	MIL-C-11015/18	CK05CW102K
15	C2	1	Capacitor Tantalum [illegible] uf	MIL-C-39003/2	CS13[illegible]
16	[illegible]	[illegible]	Capacitor Tantalum [illegible] uf	MIL-C-[illegible]/2	[illegible]

J-16-A-2

17	C4, 7, 12, 16, 19, 24, 28, 32, 35, 40, 44, 48, 52,	13	Capacitor Ceramic 470 pf	MIL-C-11015/18	CK05CW471K
18					
19	C5, 8, 10, 11, 14, 15, 18, 20, 22, 23, 26, 27, 30, 31, 34, 36, 38, 39, 42, 43, 46, 47, 50, 51, 54, 55	26	Capacitor Ceramic 5000 pf	MIL-C-11015/19	CK06CW562K
			ASS'Y USED ON 49-2[illegible]		
			* VALUES TO BE DETERMINED ON TEST		

01 2-7-66

R6 WAS 1K (IT.4), R[illegible] WAS 4.9K (IT.8) - DELETED R20, 27, 35, 42, 49, 60, 68, 76, 84, 92, 100, 108, 117 (IT.6); R134 (IT.9); R12[illegible] (IT.10) C56 (IT.14); 6, 9, 13, 17, 21, 25, 29, 33, 37, 41, 45, 49, 53 (IT.18); CR3[illegible], 38 (IT.21) ADDED ITEMS 28 & 29

02 3-28-66

[illegible] R23, 30, 37, 44, 51, 62, 70, 78, 86, 94

102, 110 & 118 FROM ITEM 7 (N2 REQ'D WAS 73) ADDED ITEM [illegible] ITEMS (1) THRU 9, 11, 12 & 13 - [illegible] TO MIL SPEC N[illegible] ITEMS 14 & 17 - ADDED /18 TO MIL SPEC N[illegible] ITEMS 15, 16 & 20 - ADDED /2 TO MIL SPEC NO ITEM 19 - ADDED /19 TO MIL SPEC NO PIX. REF. DWG NO WAS 49-400-29-401

03 5-7-66

UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES & MACHINING TOLERANCES ARE:

ANGLES ±

DIMENSIONS	UP TO 6 INCL	OVER 6 TO 24 INCL	OVER 24
FRACTIONAL	±	±	±
DECIMAL	±	±	±

[redacted] — Property of

ALLIS-CHALMERS MFG. CO., Milwaukee, Wis.

3341 M1 DEPT.

DR'N L. R. 12/22/65

TR'D

CH'D [illegible] 1-25-66

APP'D [illegible] 2/5/66

BILL OF MATERIALS

PURGE CONTROLLER MOD. 10

FIGURE 4-16A

SIMILAR TO

SCALE

SHEET 1

OF

1 2 3 4

A-C MFG. CO., MILWAUKEE, WIS. FORM 5081-6

4-16-A-3

CIRCUIT COMPONENT LIST FOR DRAWING 49-500-183-401 P/X

IT. NO.	REFERENCE DESIGNATION	NO. REQ.	DESCRIPTION	MIL SPEC. OR MFG. NAME AND CODE	MIL TYPE OR MFG. PART NO.
20	[illegible]	1	Capacitor, Tantalum 68 uf	MIL-C-26655/2	CS12[illegible]
21	CR1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, [illegible], 31, 32, 33, 34, 35, [illegible], 36	36	Diode	MSFC - 338/3	[illegible]
22	CR3, 4, 34, 42, 43, 44, 46, 47, 48, 49, 50, 51, 52	12	Zener Diode	MSFC - 338/8	SIN 747A
23	[illegible]	1	Operational Amplifier	Fairchild	[illegible] A702A
24	Q2, 3, 4	3	Transistor	MSFC - 338/108	S2N[illegible]
25	[illegible]	5	Transistor	MSFC - 338/105	S2N[illegible]
26	[illegible]	[illegible]	Dual Transistor	Fairchild or Motorola	2N2912

4-16B-1

	[illegible], [illegible], 30&31, 32&33, 34&35, 36&37				
27	R7	1	RESISTOR FIXED FILM 3.3K ±5% 0.25W	MIL-R-22684/1	RL07AD 332J
28	R147	1	RESISTOR FIXED FILM 56K ±5% 0.25W	MIL-R-22684/1	RL07AD 563J
29	C56, C61	2	CAPACITOR TANTALUM 1uf	MIL-C-26655/2	CS13BF105K
30		1	CONNECTOR	WINCHESTER	SMRE-20-PGH
31		AR.	CONDUCTOR, SOLID AWG 24	QQ-W-343	BELDEN 8522
32		A.R.	SHRINK TUBING RNF-100	MSFC-SPEC-296	276-117 OD .35 DIA
33		8	PAD, TRANSISTOR MOUNTING	TRANSIPAD PRODUCTS	10012 DAT-BLACK
34		18	TERMINAL, TURRET	USECO	2030B
35		17	PAD, DUAL TRANSISTOR	MILTON ROSS	10229
36		AR	WIRE #[illegible] AWG TYPE B	MIL-W-16878D	ALPHA # 1853
37		AR.	SOLDER SN60	QQ-S-571	TYPE RA

4-1682

38		AR	FLUX	MIL-F-14256	TYPE A
39		AR	LACING TAPE, BLACK	MIL-T-713A	ALPHA #LC134
REF			ELECTRICAL SCHEMATIC		49-400-291-401

01 2-1-66

(IT. 21)
ADDED ITEMS 27, 28 & 29
ADDED ITEM 30

02 3-28-66

ITEM #22 QTY. WAS 1

ADDED ITEMS 31 THRU 39
ITEM 21 ... WAS SINGLE A

03

UNLESS OTHERWISE NOTED
DIMENSIONS ARE IN INCHES & MACHINING TOLERANCES ARE:

DIMENSIONS	UP TO 6 INCL	OVER 6 TO 24 INCL	OVER 24
FRACTIONAL	±	±	±
DECIMAL	±	±	±

ANGLES ±

-[redacted]- Property of
ALLIS-CHALMERS MFG. CO., Milwaukee, Wis.

3341 M 1 DEPT

DR'N L.R. 12/22/65
TR'D
CH'D
APP'D

BILL OF MATERIALS

PURGE CONTROLLER
MOD. 10

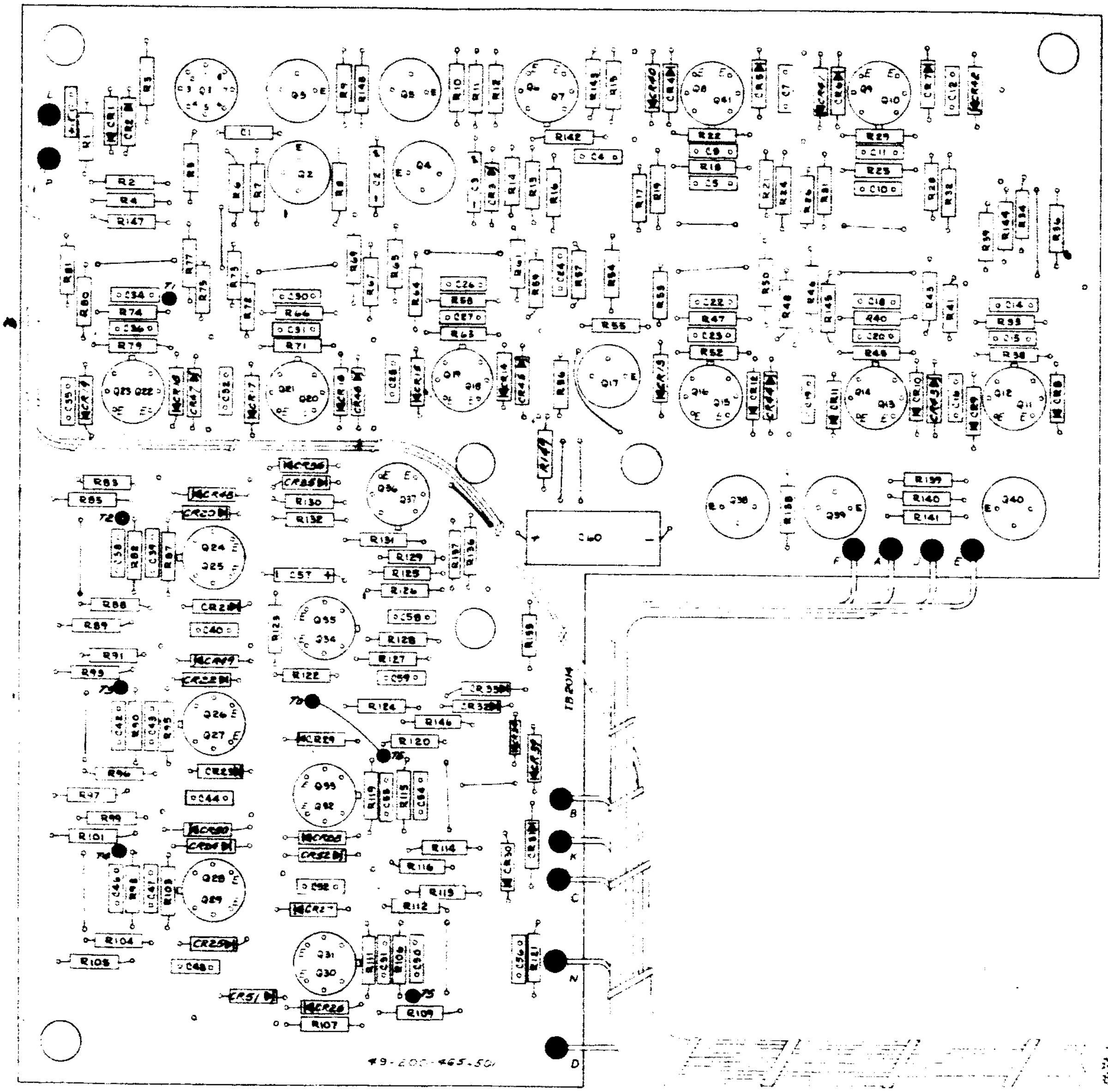
FIGURE 4-16B

SIMILAR TO:
SCALE

SHEET 2
OF 2

A-C MFG. CO. MILWAUKEE WIS.

4-16B



NOTES:

1. PRINTED CIRCUIT ... TO BE ... INSPECTED PER ...200-4

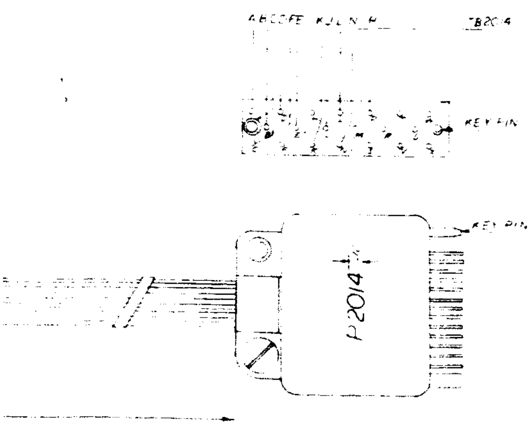
2. ALL TERMINALS SHALL BE MOUNTED ON THE PRINTED CIRCUIT BOARD PRIOR TO INSERTING ELECTRICAL COMPONENTS

3. TERMINAL IDENTIFICATION, PART & ... NUMBER ARE TO BE APPLIED ... IN POSITION SHOWN

4. AFTER QUALITY CONTROL HAS TESTED AND ACCEPTED THE PRINTED CIRCUIT ASSEMBLY APPLY A CONFORMAL COATING TO BOTH SIDES OF BOARD. EXCEPT TERMINALS T0 THRU T6 ARE TO BE KEPT CLEAR. COATING MUST COMPLY WITH MSFC PROC 257

5. REFERENCE DWG
   PRINTED CIRCUIT BOARD 43-400-...
   PRINTED CIRCUIT MASTER 43-400-...
   ELECTRICAL SCHEMATIC 43-400-...-401

6. COAT ... TERMINAL IDENTIFICATION, PART AND ... NUMBERS ... WITH CLEAR LACQUER



CONFIDENTIAL PROPERTY OF ALLIS-CHALMERS MFG. CO.

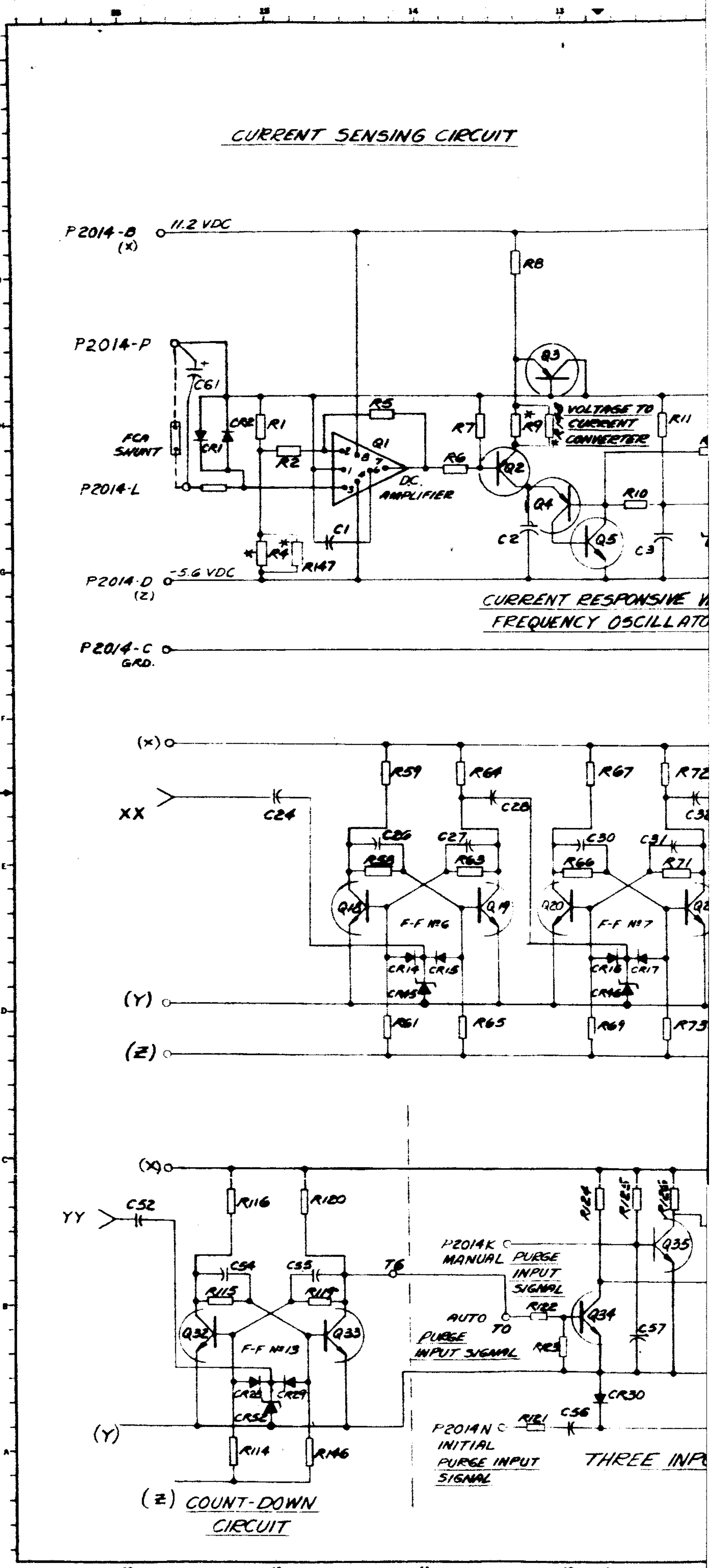
NAME: PRINTED CIRCUIT ASSEMBLY

FIGURE 4-17

SCALE: 3:1

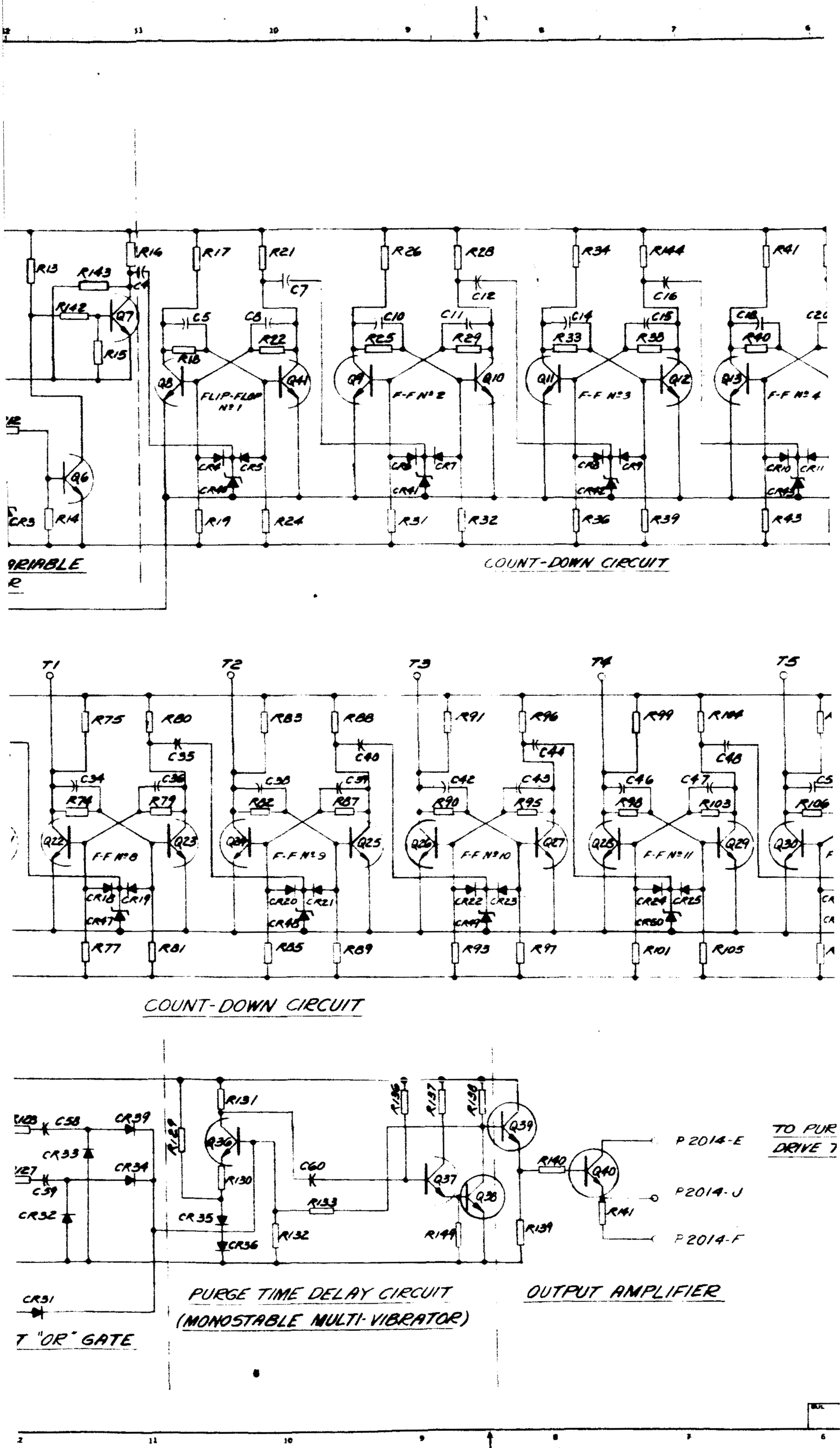
PART NO: 41500 145-401

447-2



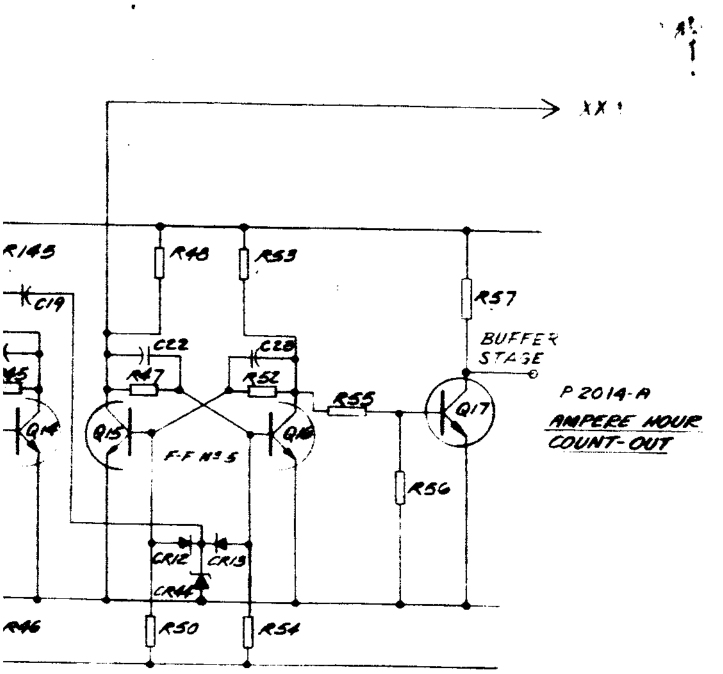
CURRENT SENSING CIRCUIT
P2014-B (X)
11.2 VDC
P2014-P
FCA SHUNT
P2014-L
P2014-D (Z)
-5.6 VDC
P2014-C GRD.
DC. AMPLIFIER
VOLTAGE TO CURRENT CONVERTER
CURRENT RESPONSIVE V
FREQUENCY OSCILLATO
XX
(X)
(Y)
(Z)
F-F Nº6
F-F Nº7
YY
F-F Nº13
COUNT-DOWN CIRCUIT
P2014K MANUAL PURGE INPUT SIGNAL
AUTO TO PURGE INPUT SIGNAL
P2014N INITIAL PURGE INPUT SIGNAL
THREE INP

4-18-1

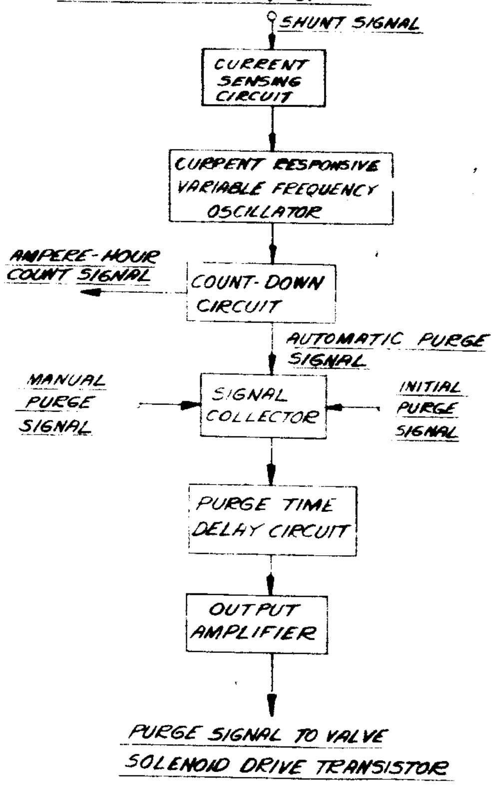


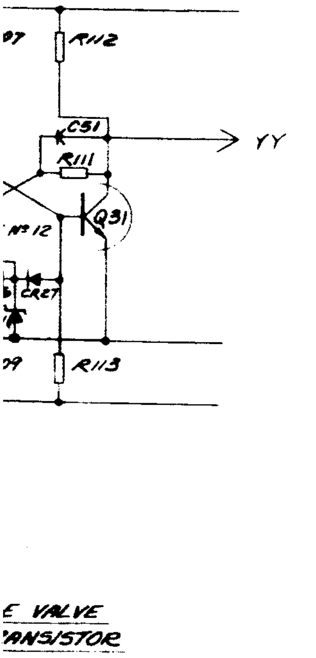
FLIP-FLOP Nº 1
F-F Nº 2
F-F Nº 3
F-F Nº 4
COUNT-DOWN CIRCUIT
T1
T2
T3
T4
T5
F-F Nº 8
F-F Nº 9
F-F Nº 10
F-F Nº 11
COUNT-DOWN CIRCUIT
PURGE TIME DELAY CIRCUIT
(MONOSTABLE MULTI-VIBRATOR)
OUTPUT AMPLIFIER
P2014-E
P2014-J
P2014-F
TO PUR
DRIVE T
T "OR" GATE

01	2-7-66	
DELETED R20, 27, 38, 42, 49, 64, 68, 76, 84, 92, 100, 108, 117, 184, 135; C6, 9, 13, 17, 21, 25, 29, 33, 37, 41, 45, 49, 53; CR 37 & 38. ADDED R149		
02	3-24-66	
DELETED R23, 30, 37, 44, 51, 62, 70, 78, 86, 94, 102, 110 & 118. ADDED CR40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51 & 52 & C61 UPDATED SYMBOLS		
03	5-30-66	



SYSTEM BLOCK DIAGRAM





FOR BILL OF MATERIAL SEE DWG 49-200-465-501

CONFIDENTIAL PROPERTY OF ALLIS-CHALMERS MFG. CO. ESCH. #3341 M/. WORKS	NAME: MODIFICATION #10 PURGE CONTROLLER SCHEMATIC
UNLESS OTHERWISE SPECIFIED: 1-PLACE DEC ± / 2-PLACE DEC ± / 3-PLACE DEC ± / ANGULAR ± — MACHINED SURFACE TEXTURE	MATL
	FIGURE 4-18 — WT
DR 12-22-65 / CH / AP — SIMILAR TO — SCALE N.H. — SHEET OF	PART NO 49-400-291-401

49-400-291-401 ISSUE 03

PRINTED IN U.S.A. FORM No 8135 1

Normal Operation - Purge cycling during normal operation is controlled by the ampere-hours (AH) of current delivered by the fuel cell. The load current signal from the fuel cell shunt is processed in a differential amplifier which provides a linear voltage to a relaxation oscillator and pulse circuit whose output pulse rate is directly proportional to the fuel cell output current. However, this pulse rate is too high to be of practical value. Therefore, this output is processed through a binary counter string which consists of a series of flip-flops until a predetermined output rate is obtained. The pulse circuit is normally adjusted for approximately four pulses per AH at the input to the binary counter string. Outputs obtained from successive flip-flops are two pulses per AH, one pulse per AH, one pulse per 2 AH, etc. until one pulse per 256 AH is obtained at the end. The purging rate is preset by selecting the appropiate tap of the binary counter string. This selected output is fed to an OR gate which feeds the delay monostable multivibrator energizing the purge valves through the valve driver. The duration of the purge is dependent upon the circuit parameters of the monostable multivibrator.

Manual Operation - If desired, a manual purge can be initiated by depressing the purge push button which supplies a trigger pulse to the OR gate circuit.

Automatic Purge at "APPLY LOAD" - When an "apply load" signal is applied to the EMCS, an initial purge signal is sent from the master controller to the OR gate for accomplishing an initial purge whenever load is first applied to the fuel cell.

4.5.4 Moisture Removal Controller - See Figure 4-19A & 19B (Drawing No. 49-200-454-401), Figure 4-20 (Drawing No. 49-300-545-401), Figure 4-21 (Drawing No. 49-200-421-401).

The moisture removal controller maintains the desired KOH concentration in the fuel cell stack by removing the excess by-product water produced by the reaction. Because the percentage of KOH concentration is a function of the moisture removal cavity pressure and the stack temperature, these two parameters are used as the controlling functions.

CIRCUIT COMPONENT LIST FOR DRAWING 49-300-585-901 P/X

IT. NO.	REFERENCE DESIGNATION	NO. REQ.	DESCRIPTION	MIL SPEC. OR MFG. NAME AND CODE	MIL TYPE OR MFG. PART NO.
1	R20, R29 R21, R24	4	Resistor Fixed Film * $\pm$ 5% 0.25 W	MIL-R-22684	
2	R_3	1	Resistor Fixed Film 2K $\pm$ 5% 0.25 W	MIL-R-22684	RL07AD202J
3	R_4, R_{12}, R_{13}, R_{16}	4	Resistor Fixed Film 2.2K $\pm$5% 0.25W	MIL-R-22684	RL07AD222J
4	R_5	1	Resistor Fixed Film 100K $\pm$ 5% 0.25 W	MIL-R-22684	RL07AD104J
5	R_6, R_1	2.	Resistor Fixed Film 8.2K $\pm$ 5% 0.25 W	MIL-R-22684	RL07AD822J
6	R_7	1	Resistor Fixed Film 6.2K $\pm$ 5% 0.25 W	MIL-R-22684	RL07AD622J
7	R_8	1	Resistor Fixed Film 220 $\pm$ 5% 0.25 W	MIL-R-22684	RL07AD221J
8	R_9	1	Resistor Fixed Film 1.8K $\pm$ 5% 0.25 W	MIL-R-22684	RL07AD182J
9	R_{10}, R_{19}	2	Resistor Fixed Film 12K $\pm$5% 0.25 W	MIL-R-22684	RL07AD123J
10	R_{11}	1	Resistor Fixed Film 5.6K $\pm$5% 0.25 W	MIL-R-22684	RL07AD562J

4-19A-1

11	R_{15}, R_{17}	2	Resistor Fixed Film 5.1K ± 5% 0.25 W	MIL-R-22684	RL07AD512J
12	R_{18}	1	Resistor CARBON 330K ± 5% 0.25 W	MIL-R-11/8	RC07GF334J
13	R_{20}	1	Resistor Fixed Film 22K ± 5% 0.25 W	MIL-R-22684	RLO7AD223J
14	R_{22}, R_{25}, R_{26}	3	Resistor Fixed Film 10K ± 5% 0.25 W	MIL-R-22684	RLO7AD103J
15	R_{23}	1	Resistor Fixed Film 470 ± 5% 0.25 W	MIL-R-22684	RLO7AD471J
16	R_{27}	1	Resistor Fixed Film 820 ± 5% 0.25 W	MIL-R-22684	RLO7AD821J
17		AR	CONDUCTOR, SOLID AWG 24	QQ-W-343	BELDEN 8022
*	R24, R21, R28, R29	4	VALUES TO BE DETERMINED AT TIME OF	TEST .	
18	C_1	1	Capacitor, Tantalum Polar 47mf	MIL-C-26655B	CS13BF476K
19	C_2	1	Capacitor, Ceramic 1000 pf	MIL-C-11015	CK05CW102K
20	CR_1	1	Diode, Zener 33 V		IN3032
21	CR2	2	Diode, Zener 3.6 V	MSFC-338/8	SIN747A
22	CR_3	1	Diode, Zener 6.8 V	MSFC-338/8	SIN754A
23	Q_1	1	Operational Amplifier	Fairchild	uA-702
24	Q_2, Q_3, Q_5, Q_7	4	Transistor	MSFC-338/105	S2N697
25	Q_4	1	Transistor	MSFC-338/108	S2N1132
26		1	CONNECTOR	WINCHESTER	SMRE-20-PGH

27	R30	1	Resistor Fixed Film 51 $\pm 5\%$ 0.25W	Mil-R-22684	RL07AD 510J
28		5	PAD, TRANSISTOR MOUNTING	TRANSIPAD PRODUCTS	10012DAT-BLACK
29		1	PAD, TRANSISTOR, DUAL	MILTON ROSS	10229
30		14	TERMINAL, TURRET	USECO	2030B
31		AR	WIRE AWG #26 TYPE B	MIL-W-16878D	ALPHA #1853
32		AR	SOLDER SN 60	QQ-S-571	TYPE RA
33		AR	FLUX	MIL-F-14256	TYPE A
34		AR	SHRINK TUBING RNF-100	MSFC-SPEC-276	276-11TODO5DIA
35		1	PRINTED CIRCUIT BOARD		49-300-546-001
36	CR4	1	DIODE, ZENER 5.1V		IN751A

01 2-1-66 ADDED ITEM 26 ADDED R28, 29 (IT. 1) [illegible]
02 5-12-66 [illegible]
[illegible] ADDED SHT 2 [illegible] ADDED [illegible] R29, R1, R2 5 REQD ADDED [illegible] REVISED [illegible]

IT. 4 WAS R5, R24, 2 REQD ADDED IT. 17 DWG. No. (4-A WAS 49-200-121
03 5-15-66 [illegible] ALL EDGES [illegible]

ASS'Y USED ON 49-200-[illegible]

DIMENSIONS	UP TO 6 INCL	OVER 6 TO 24 INCL	OVER 24
FRACTIONAL	±	±	±
DECIMAL	±	±	±

— Confidential — Property of
ALLIS-CHALMERS MFG. CO., Milwaukee, Wis.
Research - 3341 DEPT.

BILL OF MATERIAL

H_2O Cavity Pressure Control
MOD. 10

FIGURE 4-19A

SIMILAR TO: SCALE

DR'N RAR 12-2-65 CH'D [illegible] APP'D [illegible]
SHEET 1 OF 2
49-200-454-501

4-19-A-3

CIRCUIT COMPONENT LIST FOR DRAWING 49-300-545-401P1X

IT. NO.	REFERENCE DESIGNATION	NO. REQ.	DESCRIPTION	MIL SPEC. OR MFG. NAME AND CODE	MIL TYPE OR MFG. PART NO.
37	R2	1	RESISTOR FIXED FILM 1K ±5% 0.25W	MIL-R-22684	RL07AD102J
38		AR	LACING TAPE, BLACK	MIL-T-713A	ALPHA #LO134

4-19B-1

4-19-B-2

ADDED SHT 2 OF 2
03 | 5-13-66 | RGM
RME. REL.EO. 0165 ...

UNLESS OTHERWISE NOTED
DIMENSIONS ARE IN INCHES & MACHINING TOLERANCES ARE:

DIMENSIONS	UP TO 6 INCL.	OVER 6 TO 24 INCL.	OVER 24
FRACTIONAL	±	±	±
DECIMAL	±	±	±

ANGLES ±

— Confidential — Property of
ALLIS-CHALMERS MFG. CO., Milwaukee, Wis.

RESEARCH - 3341 DEPT

DR'N RAR 12-2-65
CH'D F.J.M. 4-27-66
TR'D
APP'D R.L. 2-5-66

BILL OF MATERIAL

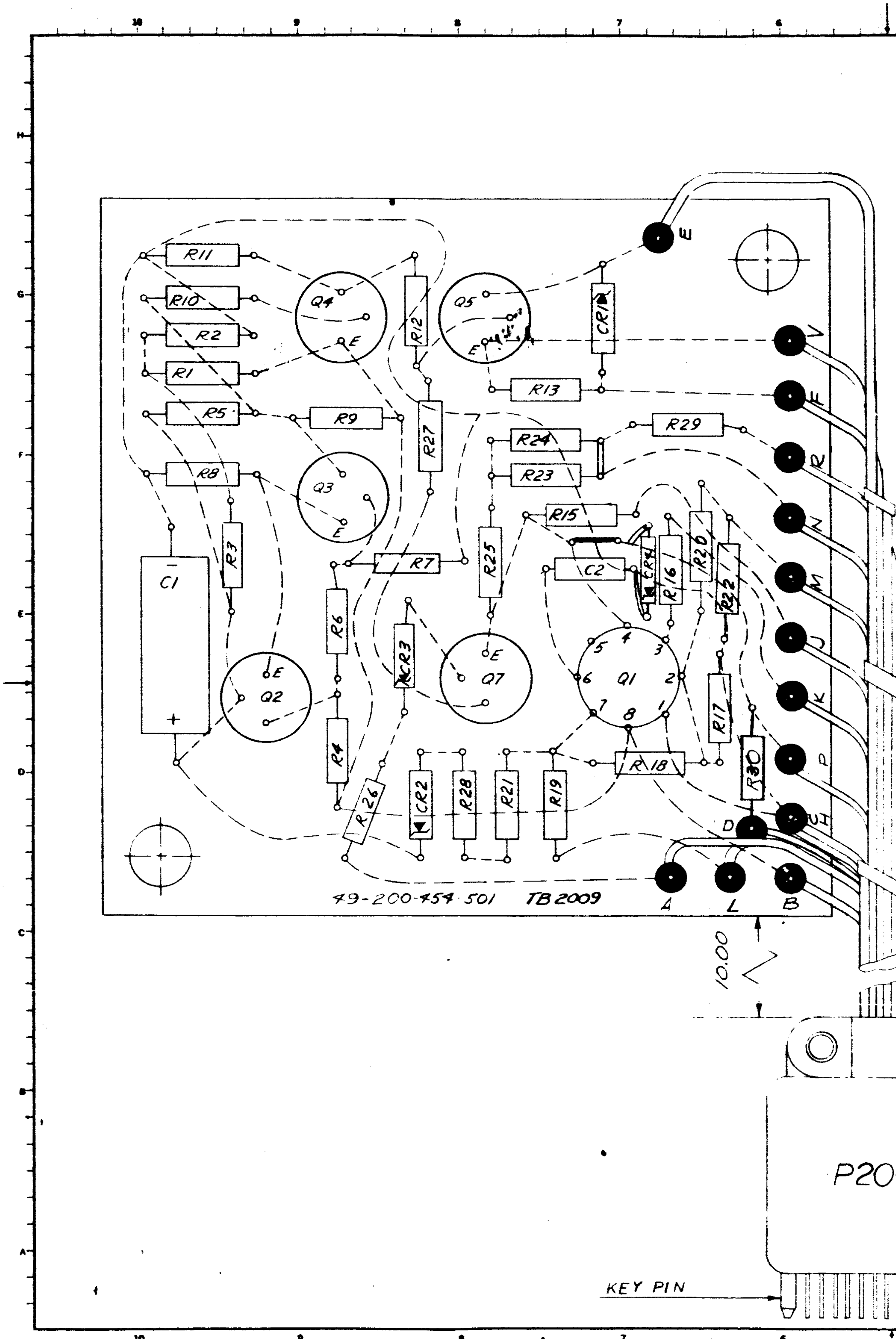
H_2O CAVITY PRESSURE CONTROL MOD. 10

FIGURE 4-19B

SIMILAR TO
SCALE

SHEET 2 OF 2

49-200-454-501


R11
R10
R2
R1
R5
R9
R8
R3
C1
Q4
Q3
Q2
Q5
Q7
Q1
R12
R27
R7
R6
R4
R26
CR3
CR2
R28
R21
R19
R13
R24
R23
R25
R15
C2
CR4
R16
R20
R22
R29
CR1
R17
R18
R30
E
V
U
R
N
M
J
K
P
H
D
A
L
B
49-200-454-501
TB 2009
10.00
KEY PIN
P20

4-20-1

01 4-27-66
REL. E.O. 0166

NOTES:

1. PRINTED CIRCUIT ASSEMBLY TO BE CONSTRUCTED AND INSPECTED PER NPC-200-4

2. ALL TERMINALS SHALL BE MOUNTED ON THE PRINTED CIRCUIT BOARD PRIOR TO INSERTING ELECTRICAL COMPONENTS

3. TERMINAL IDENTIFICATION, PART & PLUG NUMBERS ARE TO BE APPLIED IN BLACK INK .12 INCH HIGH IN POSITION SHOWN

4. COAT ALL TERMINAL IDENTIFICATION, PART & PLUG NUMBERS WITH CLEAR LACQUER

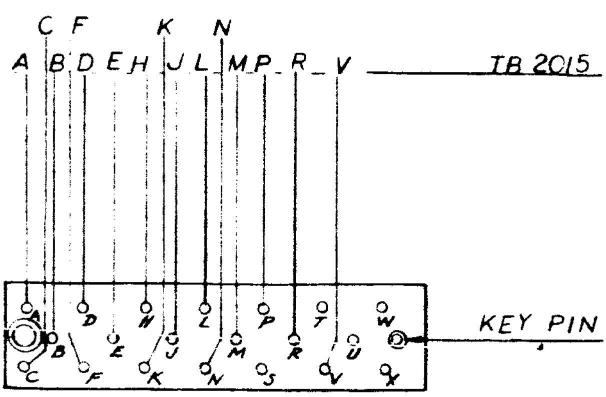
5. AFTER QUALITY CONTROL HAS TESTED AND ACCEPTED THE PRINTED CIRCUIT ASSEMBLY APPLY A CONFORMAL COATING TO BOTH SIDES OF BOARD. COATING MUST COMPLY WITH MSFC-PROC-257

6. REFERENCE DWG.

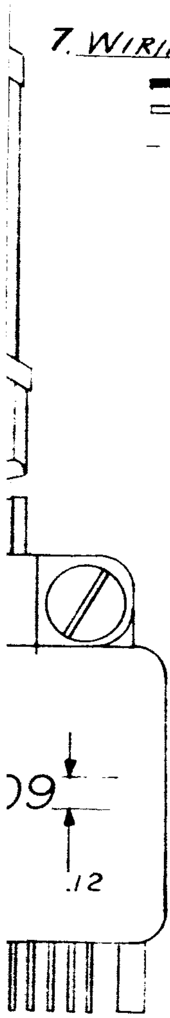
PRINTED CIRCUIT BOARD 49-300-546-001
PRINTED CIRCUIT MASTER 49-300-546-091
ELECTRICAL SCHEMATIC 49-200-421-401

7. WIRING KEY

ABOVE BOARD JUMPER
BELOW BOARD JUMPER
PRINTED CIRCUIT PATH



PLUG PIN DIAGRAM
FOR P2009



49-200-454-501
NEXT ASSEMBLY USED ON

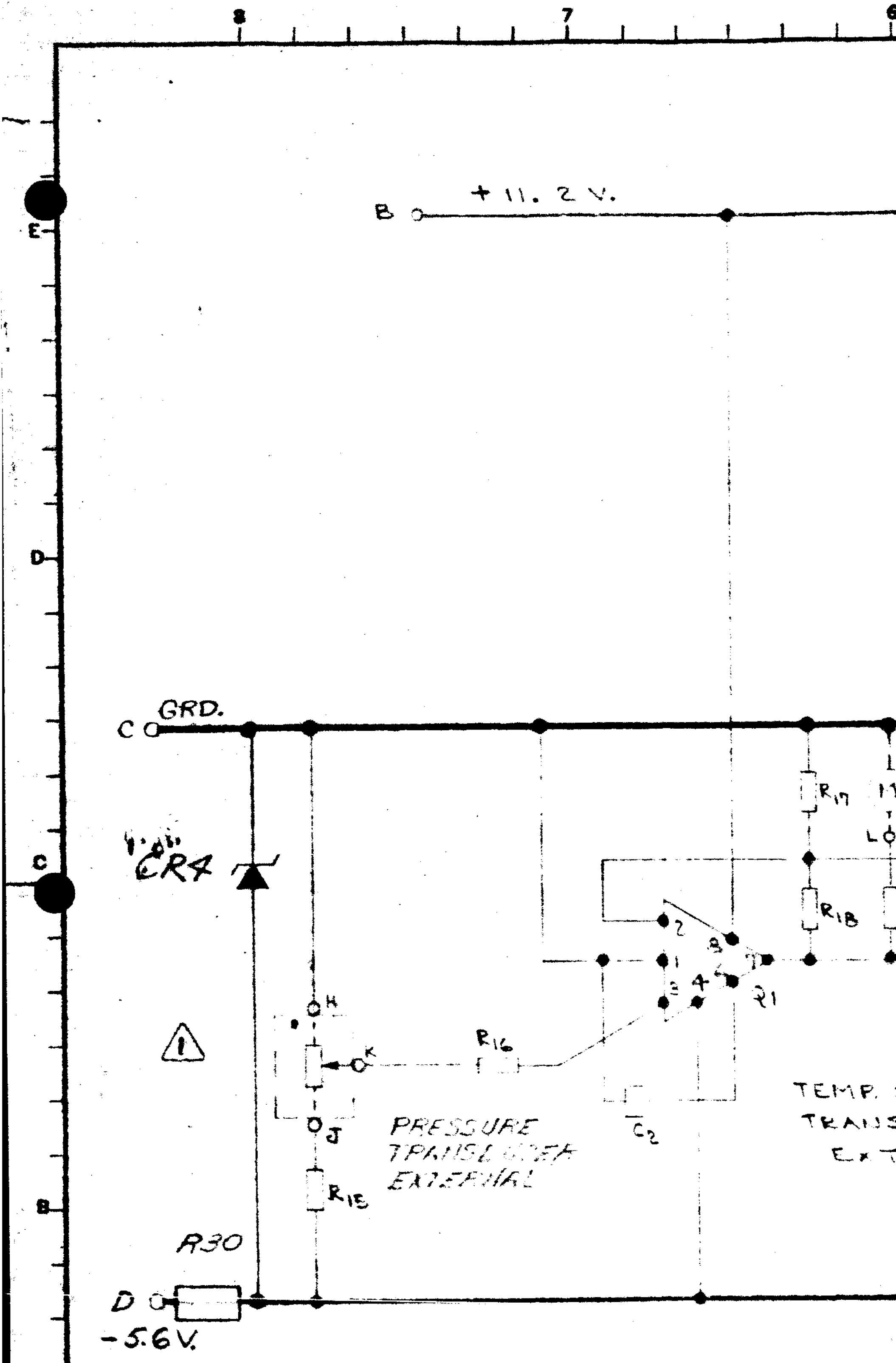
CONFIDENTIAL — PROPERTY OF ALLIS-CHALMERS MFG. CO. 3341 MI WORKS	NAME: PRINTED CIRCUIT ASSEMBLY H_2O CAVITY PRESSURE CONTROL II
UNLESS OTHERWISE SPECIFIED: 1-PLACE DEC ± ; 2-PLACE DEC ± .01 ; 3-PLACE DEC ± ; ANGULAR ± ; MACHINED SURFACE TEXTURE ✓	MATL
	FIGURE 4-20 — WT R F
DR Bill 4-5-66 ; CH [illegible] 4/25/66 ; AP ; SIMILAR TO ; SCALE 3:1 ; SHEET 1 FINAL	PART NO 49-300-545-401

ISSUE 01 — 49-300-545-401

PRINTED IN U.S.A. FORM No. 8122-1

1054-UDC

2



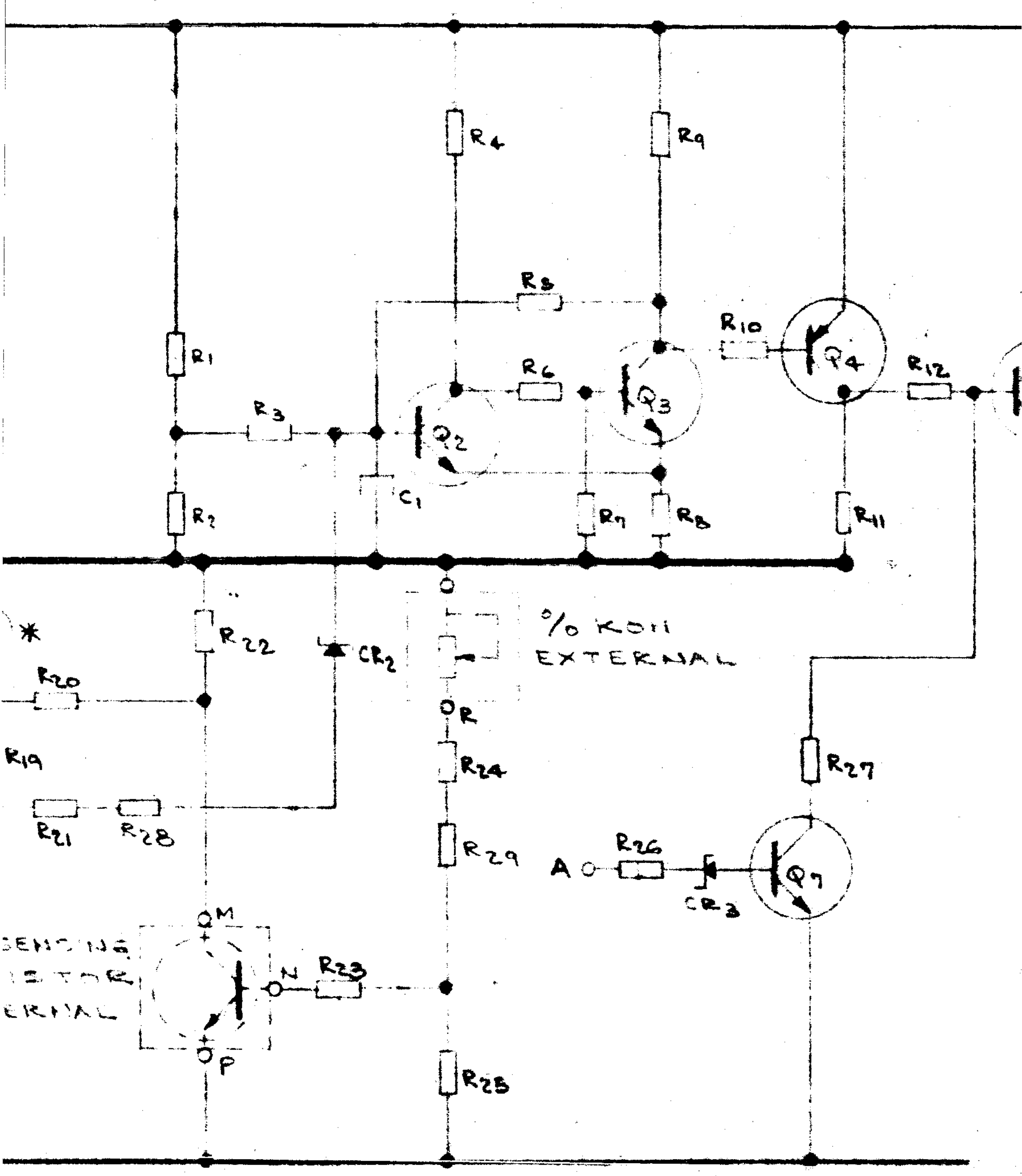
* NOTE:-

EITHER AN EXTERNAL 500-0-5
METER OR A JUMPER TO BE
BETWEEN TERMINAL 'L & S

CONNECTOR REFERENCE DESIGNA

4-21-1

BUL



*

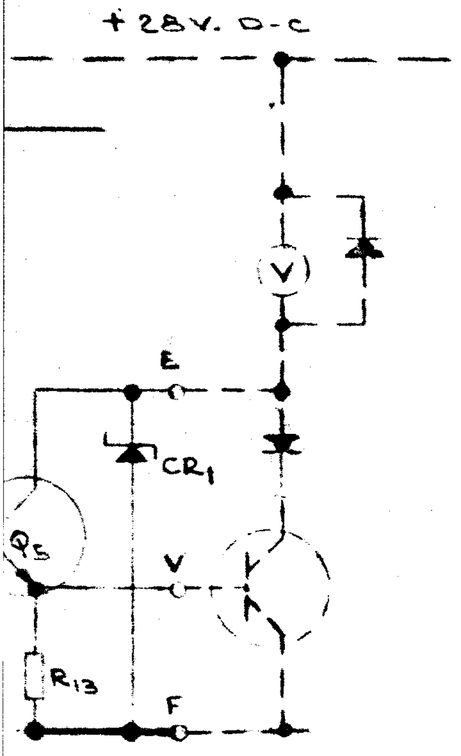
...O ωAMP
INSTALLED
ROUND.

...TION J2009

49-200-421-401 | ISSUE 03

4-21-2

01	2-6-66	
ADDED R_{28} & R_{29}		
02	3-25-66	
ADDED R30 + CR4		
03	4-6-66	RSM
E.O. 0165		



FOR BILL OF MATERIAL SEE
DWG 49-200-454-301

CONFIDENTIAL — PROPERTY OF ...-CHALMERS MFG. CO. ... W.A. WORKS	NAME H_2O CAVITY PRESSURE CONTROL MOD. 10
UNLESS OTHERWISE SPECIFIED: DEC ± DEC ± DEC ± ... MACHINED SURFACE TEXTURE	MATL
	FIGURE 4-21-3 WT R F
10-11-65 SIMILAR TO	
SCALE SHEET 1 OF 1	PART NO 49-200-421-401

PRINTED IN U.S.A.

Stack temperature is sensed by a transistor embedded in the fuel cell stack. The temperature-emitter current characteristic curve of this transistor closely matches the KOH concentration temperature - vapor pressure characteristic curve. The output of this transistor provides a reference voltage signal of the stack temperature. The moisture removal cavity pressure is sensed by a variable resistance type transducer mounted ahead of the moisture removal solenoid valve. The transducer provides a voltage signal proportional to the actual moisture removal cavity pressure.

These two signal voltages are applied to a differential amplifier. If a negative output signal is present, the pull-in coil of the moisture removal solenoid valve relay will be energized through the action of the control amplifier. The magnitude at which the valve operates is determined by the desired allowable pressure error band. A transistor interlock is provided to prevent actuating the valve unless the load has been applied.

4.5.5 <u>Master Controller</u> - See Fig. 4-22A and 4-22B (Dwg. No. 49-200-456-501), Fig. 4-23 (Dwg. No. 49-500-184-401), Fig. 4-24 (Dwg. No. 49-300-474-401). The master controller distributes the input control signals to the proper circuits and functional devices, and integrates protective controls into the fuel cell systems. The master controller operates as follows:

Under normal startup conditions, the start AND gate must have present -5.6 VDC, +11.2 VDC, +28 VDC, and the start command. Having satisfied these conditions, an "OK signal to heat" is sent to the temperature controller which turns ON the stand-by heaters and commands the warm-up heaters to be turned ON.

CIRCUIT COMPONENT LIST FOR DRAWING 49-590-184-401 P/X

IT. NO.	REFERENCE DESIGNATION	NO. REQ.	DESCRIPTION	MIL SPEC. OR MFG. NAME AND CODE	MIL TYPE OR MFG. PART NO.
1	R 26, 36, 67, 79	4	Resistor Fixed Film 1K ± 5% 0.25W	MIL-R-22684	RLO7AD 102J
2	R 5 & 8	2	Resistor Fixed Film 1.5K ± 5% 0.25W	MIL-R-22684	RLO7AD 152J
3	R 13, 23, 31,	8	Resistor Fixed Film 1.8K ± 5% 0.25W	MIL-R-22684	RLO7AD 182J
	43, 59, 66, 74, 85				
4	R 16, 18, & 63	3	Resistor Fixed Film 2.0K ± 5% 0.25W	MIL-R-22684	RLO7AD 202J
5	R 1, 12, 25, 31, 35	14	Resistor Fixed Film 2.2K ± 5% 0.25W	MIL-R-22684	RLO7AD 222J
	38, 46, 47, 55, 58,				
	69, 77, 80, & 88				
6	R 11, & 54	2	Resistor Fixed Film 3.3K ± 5% 0.25W	MIL-R-22684	RLO7AD 332J
7	R 33, 45, 76, 87	4	Resistor Fixed Film 5.6K ± 5% 0.25W	MIL-R-22684	RLO7AD 562J
8	R 29, 41, 72, 83	4	Resistor Fixed Film 6.2K ± 5% 0.25W	MIL-R-22684	RLO7AD 622J
9	R 6, 9, 23, 40,	7	Resistor Fixed Film 8.2K ± 5% 0.25W	MIL-R-22684	RLO7AD 822J

4-22A-1

	50, 71, 82				
10	R 2, 3, 17, 19, 20,	11	Resistor Fixed Film 10K ± 5% 0.25W	MIL-R-22684	RLO7AD 103J
	48, 49, 52, 56, 57				
	62				
11	R 14, 22, 32, 44				
	60, 64, 75, 86	8	Resistor Fixed Film 12K ± 5% 0.25W	MIL-R-22684	RLO7AD 123J
12	R 24, 37, 51, 68,	6	Resistor Fixed Film 22K ± 5% 0.25W	MIL-R-22684	RLO7AD 223J
	78, 21				
13		1	Printed CIRCUIT Board		49-400-342-001
14	R 10, 27, 39, 53,	8	Resistor Fixed Film 100K ± 5% 0.25W	MIL-R-22684	RLO7AD 104J
	70, 81, 15, 61				
15		2	Transistor Pad	MILTON ROSS	10229
16	R 30, 42, 73, 84	4	Resistor Fixed Film 220Ω ± 5% 0.25W	MIL-R-22684	RLO7AD 221J
17	R 4 & 7	2	Resistor Fixed Film 120Ω ± 5% 0.25W	MIL-R-22684	RLO7AD 121J
18	R 85	1	Resistor Fixed Film 56K ± 5% 0.25W	MIL-R-22684	RLO7AD 563J
19	R 89	1	Resistor Fixed Film 5.1K ± 5% 0.25W	MIL-R-22684	RLO7AD 512J
20	C 1, 3, 4, 10, 11, 13	6	Capacitor Tantalum 0.33 mf	MIL-C-26655B	CS13BF334K
21	C 7, 9, 16, 18	4	Capacitor Tantalum 10 mf	MIL-C-26655B	CS13BF106K
22	C 6, 8, 15, 17	4	Capacitor Tantalum 68 mf	MIL-C-26655B	CS13BF686K

23	C 2, 5, 12, 14	4	Capacitor Ceramic 220 pf	MIL-C-11015	CK05CW221K
24	Q 1 & 14	2	Operational Amplifier	Fairchild	UA702A
25	Q 2, 3, 4, 5, 6, 7,	20	Transistor	MSFC 338/105	S2N697
	9, 10, 11, 13, 15, 16				
	17, 18, 19, 20, 22,				
	23, 24, 26				
26	Q 8, 12, 21, 25	4	Transistor	MSFC 338/108	S2N1132
27	CR 1, 2, 3, 5, 10,	24	Diode	MSFC-338/3	SIN626
	11, 12, 13, 14, 17,				

ASSY. USED ON: 49-200-585-501 & 502

RETYPED P/L
PIX DWG. No WAS.
49-300-474-401
IT. 12 - ADDED R21
WAS (5) REQ'D.
IT. 15 WAS ADDED
IT. 18 - DELETED R21
WAS (2) REQ'D.
IT. 20 WAS IT. 17
" 21 " " 18
" 22 " " 19
" 23 " " 20
" 24 " " 21
" 25 " " 22
" 26 " " 23
" 27 " " 24

04 | 4-20-66 | KCM
E.O. 0187 RLB. RAE

UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES & MACHINING TOLERANCES ARE: | ANGLES ±

DIMENSIONS	UP TO 6 INCL.	OVER 6 TO 24 INCL	OVER 24
FRACTIONAL	±	±	±
DECIMAL	±	±	±

— Property of
ALLIS-CHALMERS MFG. CO., Milwaukee, Wis.

DEPT.

BILL OF MATERIAL
MASTER CONTROL
MOD 10

FIGURE 4-22A

SIMILAR TO:

SCALE 3

DR'N IMT 12-9-65
TR'D
CH'D FJM 9/20/66
APP'D [signature] 5/6/66

SHEET 1 OF 2

49-200-456-501

A-C MFG. CO. MILWAUKEE WIS. FORM 5081-6 5-59

CIRCUIT COMPONENT LIST FOR DRAWING 79-500-187-701

IT. NO.	REFERENCE DESIGNATION	NO. REQ.	DESCRIPTION	MIL SPEC. OR MFG. NAME AND CODE	MIL TYPE OR MFG. PART NO.
27 CONT.	18, 19, 20, 23, 24				
	26, 27, 29, 30, 37				
	38, 39, 40, 41				
28	CR 28, 31, 33	3	Diode		IN4003
29	CR 4, & 6	2	Zener Diode	MSFC-338/8	SIN751
30	CR 8	1	Zener Diode	MSFC-338/11	SIN964B
31	CR 9	1	Zener Diode	MSFC-338/8	SIN758A
32	CR 15, 16, 35, 36	4	Zener Diode	MSFC-338/8	SIN747A
33	CR 21, 22, 32, 34	4	Zener Diode		IN3034B
34	CR 25, & 7	2	Zener Diode	MSFC-338/11	SIN968B
35	K1	1	Relay Latching 24VDC	Potter & Brumfield	SL11DB
36	C19	1	Capacitor Tantalum 47 mf	MIL-C-26655B	CSI3BF476K

37	P2015 P2021	2	Connector	Winchester	SMRE-20-PGH
38	C20 & C21	2	Capacitor, Ceramic 2200 PF	MIL-C-11015	CK05CW222K
39		24	Pad, Transistor MOUNTING	TRANSIPAD PRODUCTS	10012 DAT. BLACK
40		AR	Conductor, Solid AWG 24	QQ-W-343	BELDEN 8022
41		AR	Shrink Tubing, RNF-100,	276-11 T 0D05 Dia.	
42		24	Terminal Turret	USECO	2030B
43		AR	Solder SN60	QQ-S-571	Type RA
44		AR	Flux	MIL-F-14256	Type A
45		AR	WIRE AWG #26 TYPE B	MIL-W-16878/1	49-150-009-004
Ref.		—	Electrical Schematic		49-300-474-401
46		4	SCREW #2 5/16" LG.	MS51957	MS51957-14
47		4	WASHER, PLAIN	MS15795	MS15795-804
48		4	NUT, SELF-LOCKING, HEX.	NAS1021	NAS1021004
49		AR	LACING TAPE, BLACK	MIL-T-713A	ALPHA #LC134

RETYPED P/L
IT. 28 WAS IT. 25
" 29 " " 26
" 30 " " 27
" 31 " " 28
" 32 " " 29
" 33 " " 30
" 34 " " 31
" 35 " " 32
" 36 " " 33
" 37 " " 34
" 38 " " 35
IT. 37 - ADDED REF. DESIG.
IT'S. 39 THRU 49 ADDED
P/L DWG. No. WAS 49-340-474-501
04 4-20-66 RGM
E.O. 0187 [illegible]

UNLESS OTHERWISE NOTED
DIMENSIONS ARE IN INCHES & MACHINING TOLERANCES ARE:

DIMENSIONS	UP TO 6 INCL	OVER 6 TO 24 INCL	OVER 24
FRACTIONAL	±	±	±
DECIMAL	±	±	±

ANGLES ±

– Property of
ALLIS-CHALMERS MFG. CO., Milwaukee, Wis.
RESEARCH 3341 DEPT.

DR'N JMT 12-9-65
TR'D
CH'D FJM. 4/20/66
APP'D [illegible]

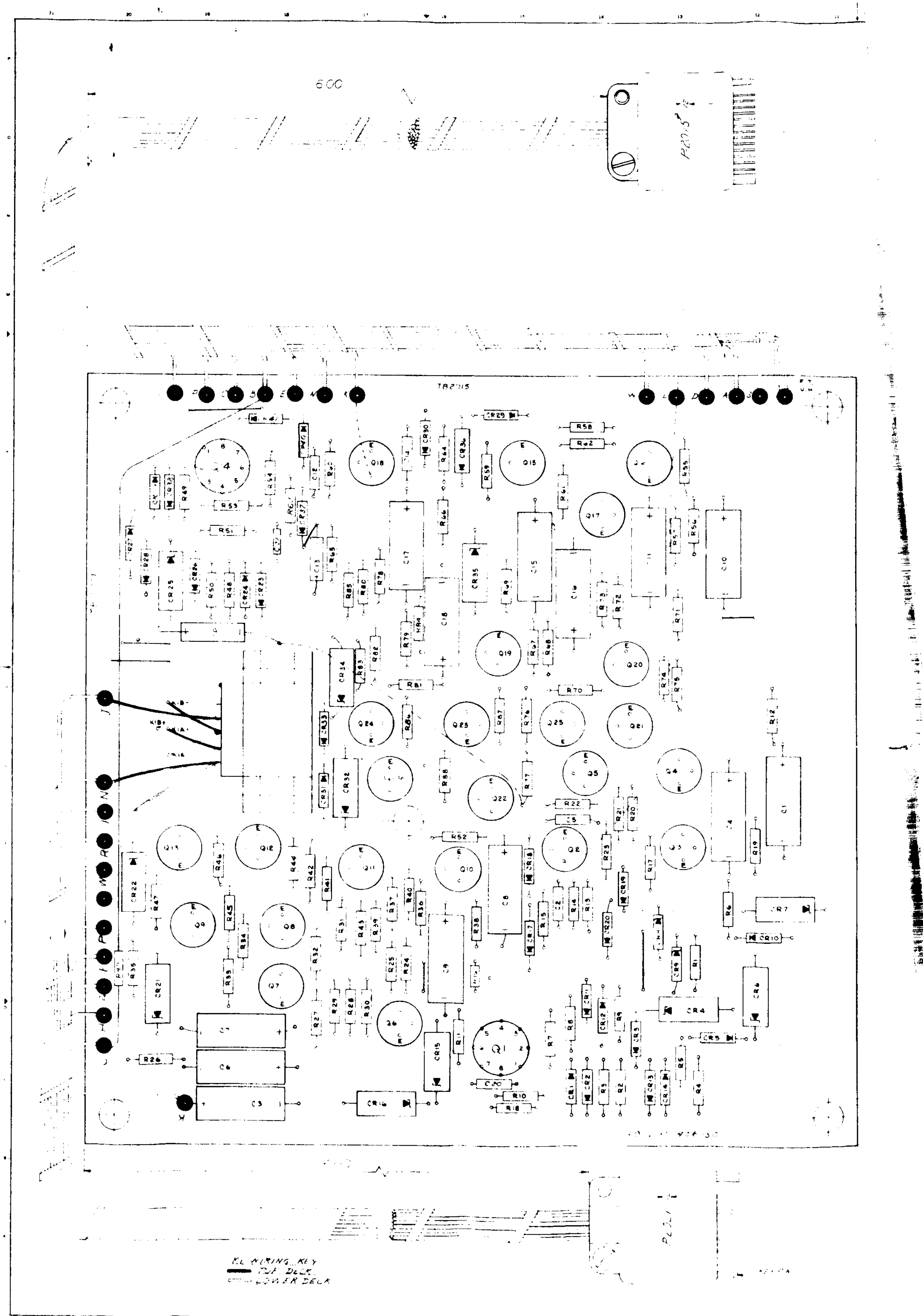
BILL OF MATERIAL
MASTER CONTROL
MOD. 10

3 FIGURE 4-22B

SIMILAR TO:
SCALE

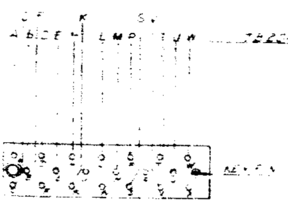
SHEET 2 OF 2

49-200-456-501

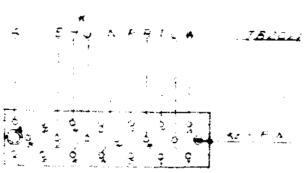

TB2115
EL WIRING KEY
UPPER DECK
LOWER DECK

NOTES:

1. ... VFC 200-4
2. ALL TERMINAL ... SHALL BE MOUNTED IN THE PRINTED CIRCUIT BOARD PRIOR TO ... ELECTRICAL COMPONENTS
3. ... MUST BE APPLIED ... WITH ... POSITION SHOWN
4. AFTER ... AND ACCEPTED, THE PRINTED CIRCUIT ASSEMBLY ... CONFORMAL COATING ... COATING MUST COMPLY WITH ... PROC ...
5. REFERENCE DWG.
   - PRINTED CIRCUIT BOARD 43-400-342-00
   - PRINTED CIRCUIT MASTER 43-400-342-29
   - ELECTRICAL SCHEMATIC 43-300-4?5-401
6. ... TERMINAL ... NUMBERS WITH CLEAR LACQUER
7. WIRING KEY
   - —— ABOVE BOARD JUMPER
   - - - - BELOW BOARD JUMPER



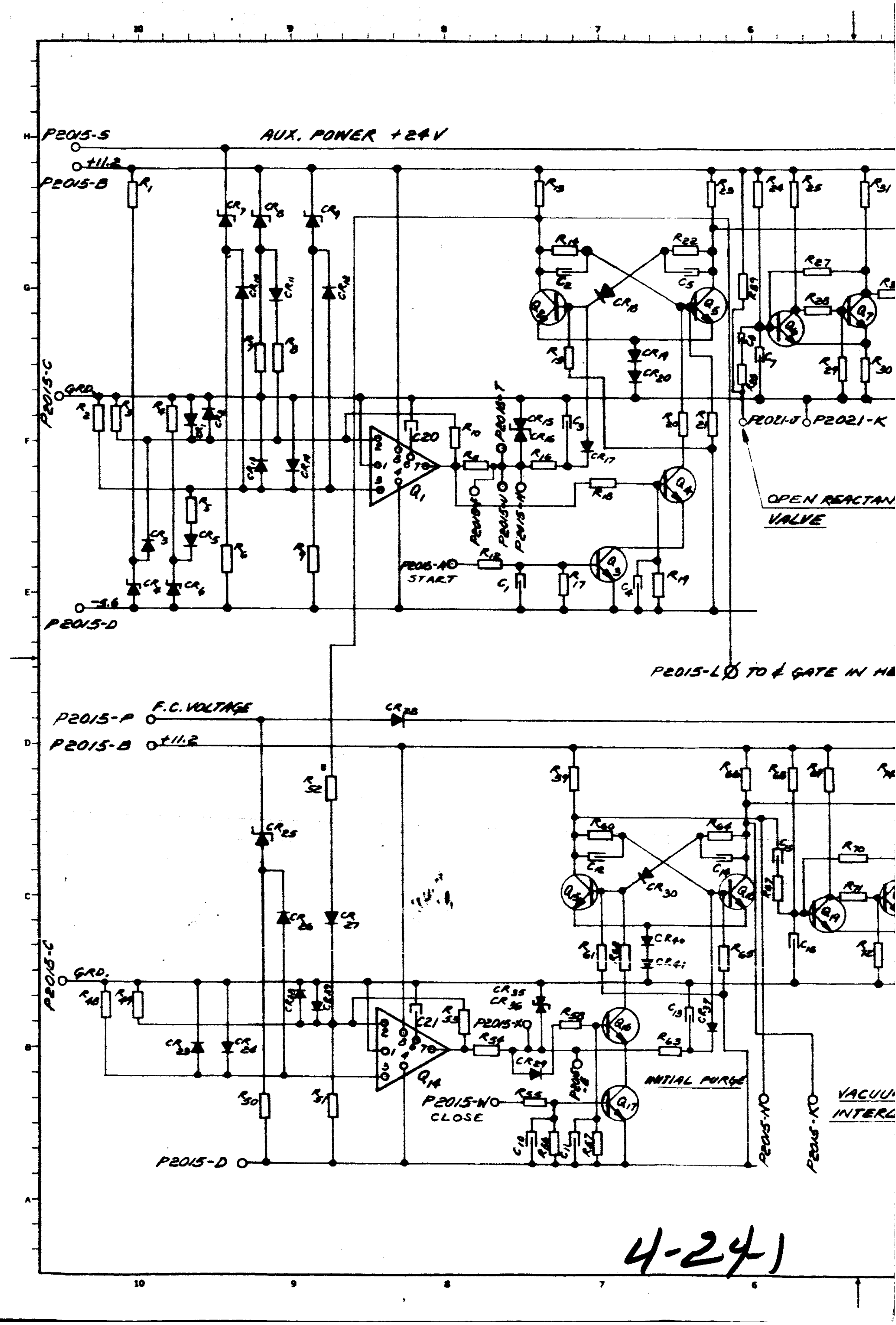
PLUG PIN DIAGRAM FOR P201S



PLUG PIN DIAGRAM FOR P202

	4? ... 0-45? 50
	NEXT ASSEMBLY USED ON
PROPERTY OF ALLIS-CHALMERS MFG. CO. 3341 ... WORKS	NAME: PRINTED CIRCUIT, ASSEMBLY MASTER CONTROLLER
UNLESS OTHERWISE SPECIFIED	MAT'L
PLACE DEC. / PLACE DEC. / PLACE DEC. / ANGULAR — MACHINED SURFACE TEXTURE	FIGURE 4-23
DR. / CH. / AP. — SIMILAR TO — SCALE 5:1 — SHEET	PART NO. 49-500-184-401

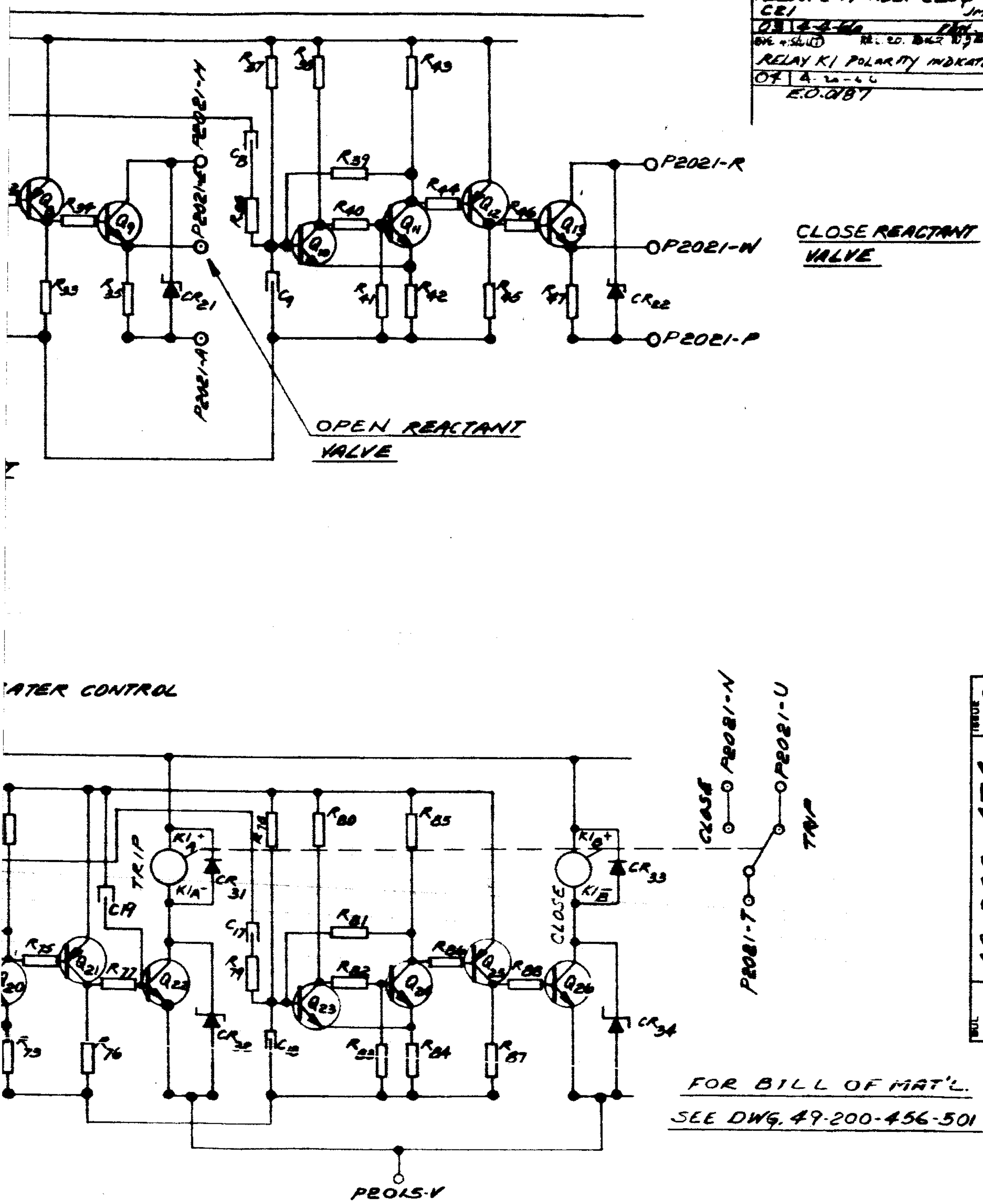
2



P2015-S
AUX. POWER +24V
+11.2
P2015-B
P2015-C
GRD.
C20
Q1
START
OPEN REACTANCE
VALVE
P2021-J
P2021-K
-9.6
P2015-D
P2015-L
TO ¢ GATE IN HE
P2015-P
F.C. VOLTAGE
P2015-B
+11.2
GRD.
C21
Q14
INITIAL PURGE
P2015-W
CLOSE
VACUU
INTERL
P2015-D

4-241

01	2-7-66		
DWG. BROUGHT UP TO DATE			
02	3-24-66		
RELOC. C-19 ADD. C20 & C21			JMT
03			
RELAY K1 POLARITY INDICATED.			
04	4-20-66		
E.O. 0187			



FOR BILL OF MAT'L. SEE DWG. 49-200-456-501

[redacted] — PROPERTY OF ALLIS-CHALMERS MFG. CO. 3341 M.I. WORKS	NAME MASTER CONTROLLER II ELECTRICAL SCHEMATIC
UNLESS OTHERWISE SPECIFIED: 1-PLACE DEC ± 2-PLACE DEC ± 3-PLACE DEC ± ANGULAR ± MACHINED SURFACE TEXTURE	MATL
	FIGURE 4-24 WT R F
DR JMT 12/13/65 CH AP SIMILAR TO SCALE N.A. SHEET / OF 1	PART NO 49-300-474-401

49-300-474 ISSUE 03

PRINTED IN U.S.A. FORM No. 81371

To apply an external load to the fuel cell, an apply load signal is applied to the load flip-flop providing the start AND gate has been satisfied. This will actuate the load relay, sent a signal to the purge controller initiating a purge cycle, and complete the interlock requirements for the water removal valve (valve cannot be opened unless load has been applied.

The reactant inlet valve is opened manually through the reactant inlet valve driver.

To shut down the fuel cell, a stop signal is applied to stop OR gate. This activates the stop flip-flop which in turn triggers the valve driver to close the reactant valve. At the same time, the same flip-flop triggers the "Main Circuit Breaker OR gate" which trips the "Load Trip Relay" through a flip-flop. Also the stop OR gate deactivates the water cavity pressure controller which closes the moisture removal valve, and interrupts the "OK to heat signal" which stops all heating untill the start command is initiated again. The liquid coolant valve will automatically close dependent on temperature. Other inputs such as: High reactant pressure, over-temperature, supply voltage and emergency stop will shut down the fuel cell in an identical manner.

'Trip main circuit command "will trip the load and close the moisture removal valve. Fuel cell voltage less than 21 VDC will trip the load and close the moisture removal valve.

4.6 CANISTER AND SUPPORT SUBSYSTEM

The canister houses the Fuel Cell Stack and Thermal Conditioning and Control Subsystems. Acting as a pressure vessel, it contains and manifolds the helium gas coolant. Brackets bolted to the canister provide a means of rigidly mounting the assembly.

4.6.1 Canister

The canister, composed of a cylindrical flanged shell and end bell, contains the gas coolant at a pressure of 40 $\pm$ 2 psia and is designed for a burst pressure of 150 psia and a proof pressure of 100 psia. The canister is fabricated from a magnesium alloy. The cylindrical shell walls are 1/16 inch thick, whereas the spun end bell walls are 3/32 inches thick. Sealing between the cylindrical shell flanges, the end bell, and the fuel cell stack bottom end plate is accomplished with elastomer "O" rings.

Provisions are made on the cylindrical portion of the end bell for entry and return of the liquid coolant as well as entry of electrical blower leads and thermal instrumentation. The bottom end plate has a port provision for the initial charging or depressurization of the gas coolant in the canister. The canister pressure is continually monitored through this port by a 0-50 psia absolute - pressure transducer. A 45 psia relief valve is provided for over pressure protection.

4.6.2 Support

A rigid support is provided by four brackers that mechanically fasten to the flanges of the cylindrical canister shell as shown in Figure 4-25. The

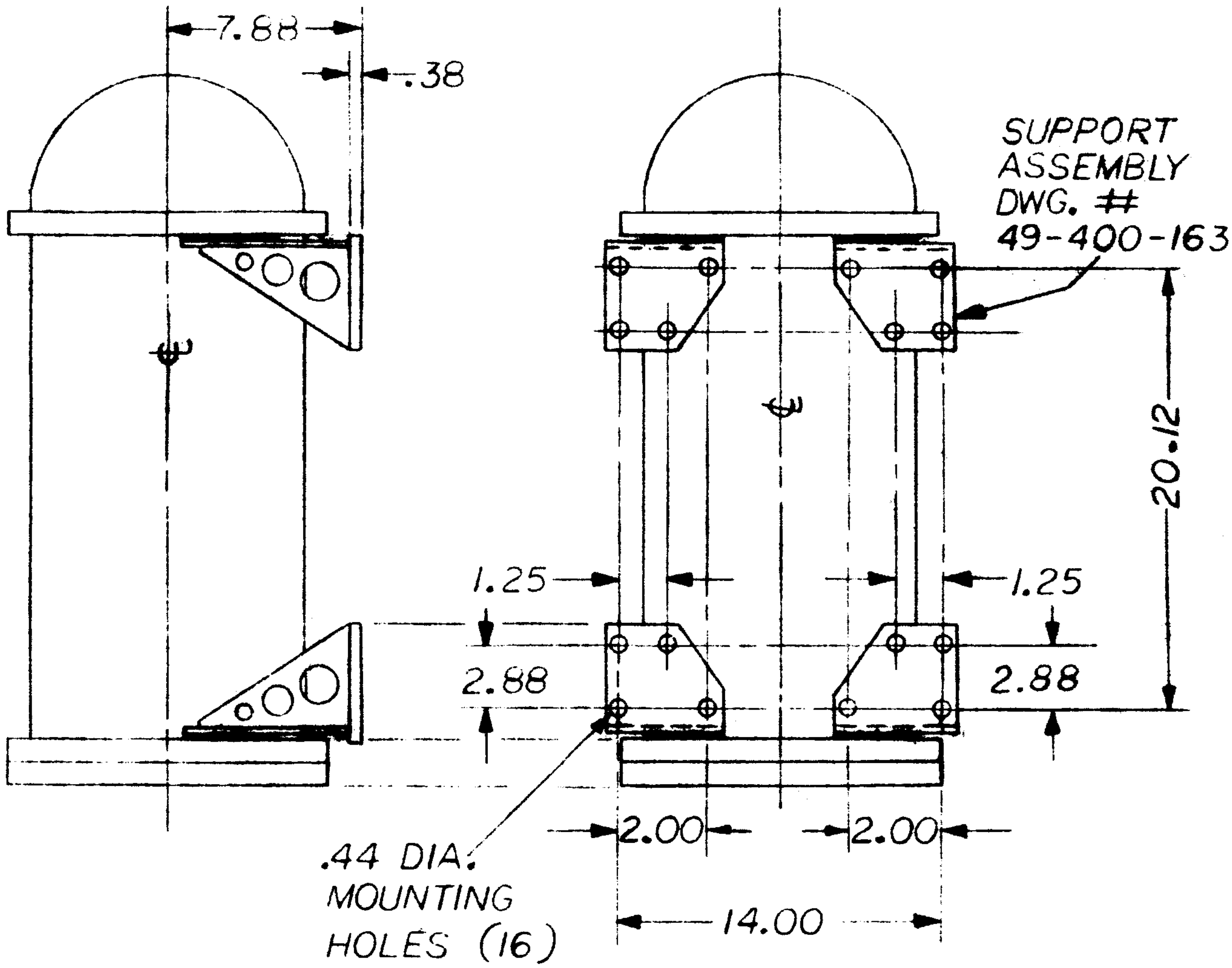


FIGURE 4-25

CONFIDENTIAL — PROPERTY OF
ALLIS-CHALMERS MFG. CO.
3341 W.A. WORKS

UNLESS OTHERWISE SPECIFIED:
1-PLACE DEC ±
2-PLACE DEC ±
3-PLACE DEC ±
ANGULAR ±

MACHINED SURFACE TEXTURE

NAME

MATL F.C.A. BULKHEAD MOUNTING DETAIL

WT R F

DR UL 8-10-65
CH
AP

SIMILAR TO

BUL

SCALE NONE

SHEET

PART NO 49-100-596

ISSUE 01

PRINTED IN U.S.A.

FORM No. 8130-1

brackets attach to the canister through thermal insulating mounts to minimize losses due to thermal conduction.

The Reactant Control and Conditioning Subsystem is also attached to the canister through thermal insulation mounts, thereby isolating it from the canister, except for the tube connections.

4.7 TEST INSTRUMENTATION

4.7.1 Thermocouple Instrumentation

There are 12 iron-constantan thermocouples located in and outside of the Fuel Cell to permit detailed temperature analysis. (Figure 1-2A and 1-2B (Drawing No. 49-500-125-404), Fuel Cell System Interface Schematic, shows the location of the thermocouples. Figure 2-9, Sheet 5 of 5 (NASA Interface Connections) gives the location and function of each thermocouple.